A temperature profile of the beginning stages of a blueberry supply chain

by

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third-party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

Due to the changing lifestyle choices of the modern-day consumer, the demand for blueberries has risen significantly in recent years. Exporters of blueberries are losing money linked to lower quality fruit arriving at their final destination. Studies have proven that various factors could play a role in the decrease in fruit quality, especially in the initial stages of a supply chain. These factors include the geographical location of the farms, different methods of loading, unloading and transportation on and from farms to the centralised cold storage facility, and the trade-off between the time of picking and fruit quality. The objective of this research was to identify whether the different logistics processes implemented, specifically in the beginning stages of the blueberry supply chain, have an influence on the quality of the fruit. Through mapping and tracking of the blueberry temperature profiles, the researcher was able to identify where temperature breaks occurred. Furthermore, the research determined whether the current logistics processes implemented by Company X are the most effective, and if not, what should be improved. The study followed a deductive research approach and utilised a case study research strategy. It used a mixed-method research approach by collecting quantitative and qualitative data. Semi-structured interviews, informal observations and questionnaires were used in the study. iButtons® were used on all the farms to record ambient temperatures experienced by blueberries throughout the beginning stages of the blueberry supply chain. Temperature trials were conducted on three farms in Gauteng and three farms in the Western Cape. Various temperature fluctuations were recorded during the beginning stages of the blueberry supply chain. This could have been avoided if protocols were followed more strictly. The lack of controlled humidity could also be a contributing factor to the loss of moisture identified in the quality reports. The long average time spent during the Harvest and Transportation stage was identified as something that needs to be improved upon. In addition, the insufficient pre-cooling and lack of separate refrigerated rooms in the cold rooms on the farms in the Western Cape were identified as an area of concern. Lastly, decreasing the number of temperature fluctuations during the Forced Cooling stage should be a priority. In conclusion, the research highlighted problem areas within the beginning stages of a blueberry supply chain. Furthermore, it identified the best performing candidates during each stage, which should be used as a benchmark by Company X. By minimizing the breach of protocols and improving the beginning stages of the blueberry supply chain, a better-quality product is ensured, thus, reducing costs and food wastage.

Keywords: blueberry supply chain; chilling injury break; chilling injury spike; cold chain management; South African fruit industry; temperature break; temperature spike.

Opsomming

Weens die veranderende leefstylkeuses van die moderne verbruiker het die vraag na bloubessies aansienlik gestyg die afgelope paar jaar. Uitvoerders van bloubessies verloor inkomste indien swak gehalte vrugte by die finale bestemming aankom. Studies het getoon dat verskeie faktore ’n rol kan speel in die afname in vrugkwaliteit, veral tydens die eerste stadium van die voorsieningsketting. Hierdie faktore sluit die volgende in: geografiese ligging van die plase, verskillende laai-, aflaai- en vervoermetodes op die plase en vanaf die plase na die gesentraliseerde koelkamer fasiliteite, asook die kompromie tussen pluktyd en vrugkwaliteit. Die doelstellings van hierdie navorsing was om te identifiseer of die verskillende geïmplementeerde logistieke prossesse, spesifiek in die beginstadium van die bloubessie voorsieningsketting, ’n invloed het op die kwaliteit van die vrugte. Die kartering en nasporing van bloubessie temperatuurprofiele het die navorser in staat gestel om te identifiseer waar moontlike temperatuur afwykings plaasvind. Verder het die navorsing ondersoek of Maatskappy X se huidige geïmplementeerde logistieke prosesse effektief is, en indien nie, watter verbeteringe kort. Die studie het ’n deduktiewe navorsingsbenadering gevolg asook van ’n gevallestudie navorsingstrategie gebruik gemaak. ’n Gemengde-metode navorsingsbenadering is gebruik deur kwantitatiewe en kwalitatiewe data te versamel. Semi-gestruktureerde onderhoude, informele waarnemings en vraelyste is gebruik in die huidige studie. iButtons® is op al die plase gebruik om die bloubessies se omgewingstemperatuur te meet vir die beginstadium van die bloubessie voorsieningsketting. Temperatuur steekproewe is op drie plase in Gauteng en drie plase in die Wes-Kaap uitgevoer. Verskeie temperatuur afwykings is waargeneem vir die beginstadium van die bloubessie voorsieningsketting. Dit kon vermy geword het indien protokolle strenger gevolg is. Die gebrek aan beheerde humiditeit kan ook ’n bydraende faktor wees tot die vogverlies geïdentifiseer in die kwaliteitverslae. Die lang gemiddelde tyd gespandeer tydens die Oes-en-Vervoer stadium is geïdentifiseer as ’n aspek waarop verbeter kan word. Verder is onvoldoende voorverkoeling en ’n tekort aan afsonderlik verkoelde kamers in die koelkamers op plase in die Wes-Kaap geïdentifiseer as kommerwekkend. Laastens moet die vermindering van die aantal temperatuurafwykings gedurende die Gedwonge-Verkoeling stadium ’n prioriteit wees.Ter opsomming het die navorsing probleemareas gedurende die beginstadiums van ’n bloubessie voorsieningsketting uitgewys. Verder het dit die bes presterende kandidate vir elke stadium geïdentifiseer, wat as ’n maatstaf deur Maatskappy X gebruik kan word. Deur afwykings vanaf protokolle te verminder asook die beginstadium van die bloubessie voorsieningsketting te verbeter, kan ’n

beter kwaliteit produk verseker word, wat sodoende onkoste and voedselvermorsing kan verminder.

Sleutelwoorde: bloubessie voorsieningsketting; koue besering breek; koue besering piek; koue ketting bestuur; Suid-Afrikaanse vrugtebedryf; temperatuur breek; temperatuur piek.

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Acronyms and Abbreviations

ANOVA	Analysis of Variance
CSC	Centre for Statistical Consultation
CSCMP	Council of Supply Chain Management Professionals
°C	Degrees Celsius
DESC	Department Ethics Screening Committee
DX	Direct expansion
e.g.	Exempli gratia (for example)
etc	Et cetera (and so forth)
g	Gram
GAPs	Good Agricultural Practices
GHPs	Good Hygienic Practices
GCC	Gulf Cooperation Council
IIR	International Refrigeration Institute
km	Kilometre
NDA	Non-disclosure agreement
PPECB	Perishable Produce Export Control Board
SABPA	South African Berry Producers' Association
SAWS	South African Weather Service
SHBs	Southern highbush cultivar
QC	Quality control

Chapter 1: Introduction

1.1. Introduction

The fruit and vegetable industry is an essential part of the agricultural sector in South Africa. According to Agriculture (2019), the South African fruit and vegetable industry contributes up to 53.4% towards household food security and plays an instrumental role in economic development. The ever-growing South African fruit industry is commonly known for three fruit types, namely citrus, deciduous, and subtropical fruit. However, due to changing lifestyle choices of the modern-day consumer, the exotic fruit types, specifically blueberries, have received a lot of attention in recent years (Dodgson, 2015).

Farmers in South Africa identified this gap in the market and as a result, the production of blueberries increased from 11 700 tons in the 2018/2019 season to 18 000 tons for the 2019/2020 season. The export volumes for the 2019/2020 season amounted to 12 282 tons, with exports accounting for 68% of the industries output (African News Agency, 2020). This growth in terms of interest in blueberries is not a "one season success story", as the average growth in the tonnage of blueberries produced for the last three seasons is estimated at 73%. Blueberries do not only contribute towards food security, but also help to create jobs. Hortgro (2018) states that 2.96 jobs are created per hectare of blueberries planted, as farms need workers to plant, harvest, inspect and package the blueberries.

Blueberries are perishable products, and therefore, the cold chain must be efficient, i.e., the presence of temperature breaks must be kept to a minimum at all times. Blueberries need to be forced air cooled within six hours after harvesting to a temperature of 0ºC to ensure a longer shelf life (Fresh Food Trade SA, 2018). Blueberries are a labour-intensive job, where the correct logistical processes need to be followed and the blueberries need to be handled with care. Forced air cooling is only one of the processes that need to be implemented in order for the blueberries to meet the criteria for exportation. Other processes include harvesting, transportation, and pre-cooling. In addition, not all farmers use the same logistical processes and technologies.

Although various studies have been conducted regarding different cold chains within the fruit industry and minimizing the presence of temperature breaks, some gaps still exist. Company X has conducted research along the cold chain of blueberries and identified concerns over, specifically, the beginning stages of the cold chain and the logistical processes followed.

Therefore, this study focuses on identifying whether the different logistics processes implemented, specifically in the initial stages of the blueberry supply chain, from the picking process until they are loaded into cold storage, have an influence on the quality of the fruit.

1.2. Motivation

This study aims to identify where (if anywhere) temperature breaks occur along the beginning stages of a blueberry supply chain, specifically from the bushes on the farms to the cold storage facility. Particular focus is placed on blueberries from farms in different districts in South Africa, namely Gauteng and the Western Cape. By identifying where temperature breaks (if any) occur along the beginning stages of a blueberry supply chain, it will enable Company X to minimize these breaks, thus, maximizing profits in the future.

1.3. Problem Statement

Exporters of blueberries lose money because of a decrease in quality while in transit to their final destination. Research has shown that with other products, for example, table grapes, apples, pears, and plums, this decrease in quality is mainly because of ineffective export cold chains (Haasbroek, 2013). The same assumption can be made for blueberries. Valentine & Goedhals-Gerber (2017:3) proved that various factors could play a role in the decrease of quality in the first section of an apple supply chain. These include the geographical location of the farms, different methods of loading, unloading and transportation on and from farms to the centralised cold storage facility, and the trade-off between the time of picking and fruit quality. This study investigates whether similar factors have an impact on the temperature profile of blueberries. In the event that temperature breaks do occur, this study provides possible answers on how to effectively manage the temperature fluctuations.

1.4. Research Questions

To achieve the desired aim and objectives of this study, the following research questions are investigated:

1. Do the logistics processes in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage, have an influence on the quality of the fruit?
2. Do the different handling techniques for loading, unloading and transportation on and from farms to the centralised packhouse facility impact the temperature profile of blueberries?
3. Does the geographical location of farms in the various districts have an impact on the temperature profile of blueberries?
4. Do temperature breaks occur in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage?
5. Is there a link between the time of harvesting and fruit quality, specifically for the southern highbush variety?

1.5. Research Objectives

The objectives and related research questions of this study are shown in **Table 1.1**.

Table 1.1: Research objectives and related research questions

Research Questions	Research Objectives	Addressed in Chapter
Do the logistics processes in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage, have an influence on the quality of the fruit?	To identify whether the logistics processes implemented, specifically in the beginning stages of the blueberry supply chain, have an influence on the quality of the southern highbush variety.	Four and Five
Do the different handling techniques for loading, unloading and transportation on and from farms to the centralised packhouse facility	To identify which handling technique for loading, unloading and transportation on and from farms to the centralised packhouse facility is the most effective in terms of	Four and Five

impact the temperature profile of blueberries?	the least number of temperature breaks.	
Does the geographical location of farms in the various districts have an impact on the temperature profile of blueberries?	To identify the effect that different geographical locations of farms have on the temperature profile of blueberries.	Four and Five
Do temperature breaks occur in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage?	To identify whether temperature breaks occur in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage.	Four and Five
Is there a link between the time of harvesting and fruit quality, specifically for the southern highbush variety?	To identify whether a link between time of harvesting and fruit quality exists, specifically for the southern highbush variety.	Four and Five

Source: Created by the author for the purpose of this study

1.6. Aim and Purpose

The aim of this research is primarily to identify whether the different logistics processes implemented, specifically in the beginning stages of the blueberry supply chain, starting from the picking process until the blueberries are loaded into cold storage, have an influence on the quality of the fruit. Through mapping and tracking of the blueberry temperature profiles, the researcher can identify weak points where possible temperature breaks occurred. With this information the researcher can help exporters of blueberries, to identify and address the problem of temperature breaks in the initial stages of the blueberry cold chain. Whereafter, this study strives to determine the link between logistics processes, temperature breaks and fruit quality.

Once the investigation is complete, the goal is to ascertain whether the current logistics processes implemented are the most effective and if not, to determine what should be improved. The research, therefore, strives to equip Company X with answers to unanswered questions in terms of the beginning stages of the blueberry export cold chain.

1.7. Conceptual Framework

Figure 1.1 is an illustration of the conceptual framework used for this study. A conceptual framework helps the researcher to demonstrate the proposed flow of the study and shows the different sections of the research. **Figure 1.1** shows that the conceptual framework consists out of three main sections. The research problem identifies the problem being investigated. The research objectives and research questions are used to give more insight in terms of the topic as well as provide possible solutions for the study. Feedback is used to provide the findings of the study as well as possible solutions. The conceptual framework was used as an outline by the researcher to achieve a desirable outcome.

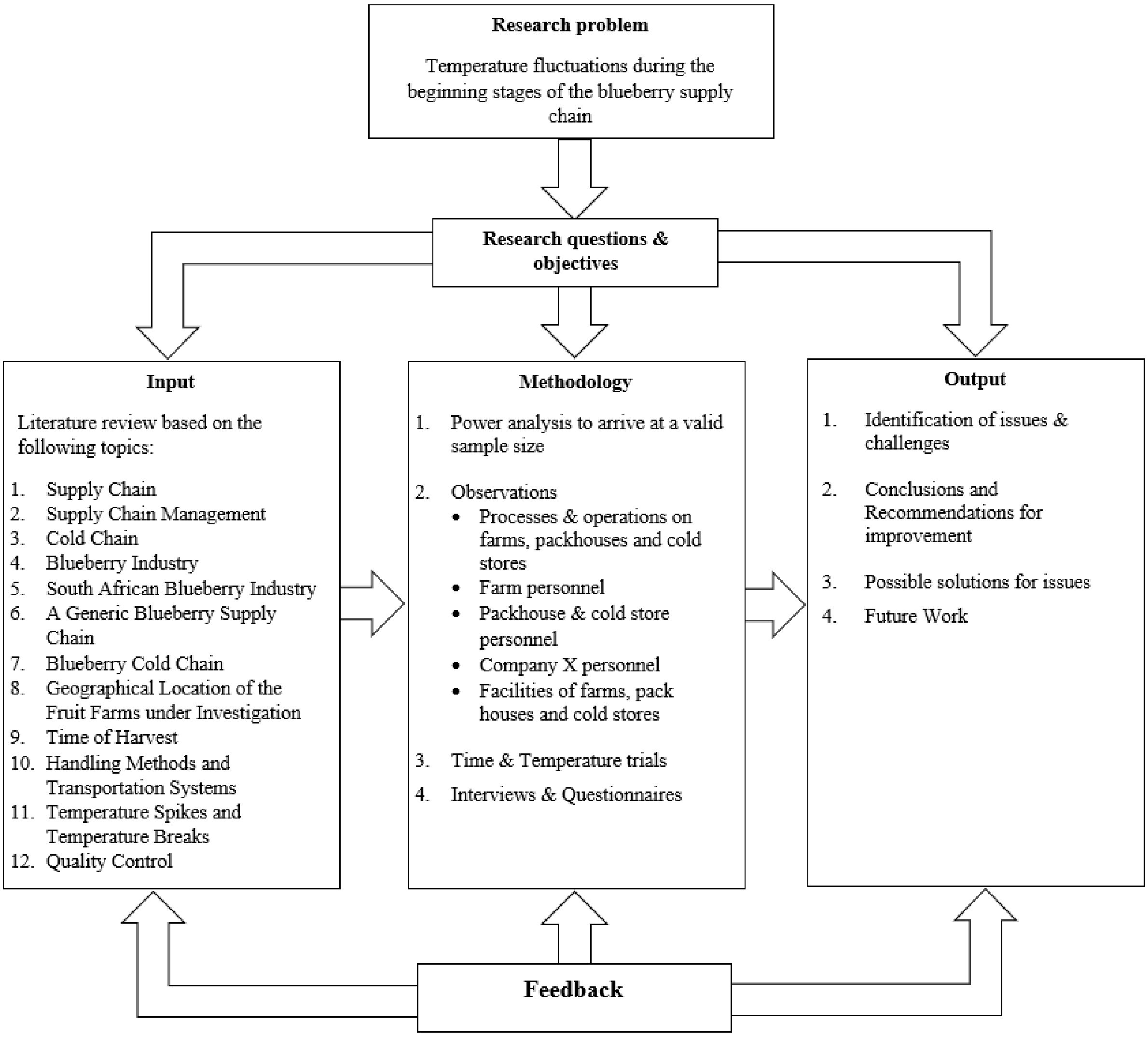


Figure 1.1: Conceptual framework of research study
Source: Created by the author for the purpose of this study

1.8. Outline of the study

Chapter 2: Literature Review

This chapter, which is divided into various sub-sections, introduces the main concepts forming part of this study. It firstly defines a supply chain and explains the role of a supply chain in a company. Secondly, the section on supply chain management further introduces the importance of a supply chain and explains how different supply chains can be combined with the use of supply chain management to create value for customers. Thereafter, a specific type of supply chain, known as the cold chain, is discussed. The importance of a cold chain with regards to perishable produce is explained as well as the added benefits of maintaining a cold chain. The Blueberry Industry section includes a background on the blueberry industry, with a particular focus on blueberry cultivars. The South African blueberry industry section focuses on the growth of the South African blueberry industry and the main areas of production. In order to gain a better understanding of how the above-mentioned sections are integrated, a section on a generic blueberry supply chain provides an overview of how a generic blueberry supply chain works. Thereafter, the beginning stages of the blueberry cold chain are discussed, starting from harvesting to where the fruit ends up in the cold store (forced cooling). Next, Chapter 2 discusses the geographical location of the fruit farms under investigation as well as the importance of time of harvest, handling methods and transportation systems used. Furthermore, a temperature spike and temperature break for blueberries is defined to aid as a parameter for the study. Lastly, quality control, with reference to the quality reports received from Company X, are discussed.

Chapter 3: Research Design and Methodology

The chapter begins by defining constructs and variables and discussing the constructs and variables applicable to this study. Thereafter, the studies' research philosophy, research approach and research design are explained. In addition, this chapter provides important information regarding how data was collected, the methods used to analyse the data and how the study aimed to provide reliable and valid data. Furthermore, this chapter points out the limitations of the study as well as ethical considerations taken into account during the study.

Chapter 4: Descriptive Data Analysis

The chapter starts with providing an overview of the blueberry supply chains and protocols implemented on the farms of Company X. Thereafter, the feedback received from interviews with relevant role players within the blueberry industry is discussed. International best practices as well as an in-depth discussion of the observations made during the research is followed, with the data collected graphically depicted using tables and graphs.

Chapter 5: Interpretation of results

This chapter involves the interpretation of the results as discussed in Chapter 4, to clarify what the results mean. The main findings and trends are identified, and possible reasons are provided for each. This chapter is of utmost importance since it can potentially indicate areas where improvements are required as well as areas of excellence. Furthermore, with sufficient evidence it will enable Company X to either make certain changes in the blueberry cold chain or investigate the matter further.

Chapter 6: Conclusions, recommendations, and future work

The concluding chapter highlights the main findings of the research and determines whether enough evidence has been provided to answer the research questions within this study. In addition, the researcher lists possible solutions to the problem areas identified and provides short-, medium- and long-term recommendations to improve certain areas within the blueberry cold chain. Lastly, suggestions for future research topics are given.

Chapter 2: Literature Review

2.1. Introduction

The goal of the Literature Review chapter is to introduce various concepts that are fundamental to the current study. Therefore, this chapter attempts to build on previous studies, but also to develop a new way of thinking around existing topics. Secondary research in the form of books, journals, and academic articles and primary research in the form of interviews, were used to gather information that is relevant and accurate. It is important to note that all sections in this chapter are intertwined and should be read with the understanding that each section contributes holistically to this study. Sections 2.2 to 2.6 provide the reader with background information regarding the blueberry industry, whereas in sections 2.7 to 2.13 specific focus is placed on the different aspects of the blueberry cold chain.

This chapter starts by introducing and defining the concepts of supply chain (section 2.2) and supply chain management (section 2.3). The reader is provided with knowledge regarding how raw materials reach the end consumers and all the intricacies involved to accomplish this. In section 2.4, Cold Chain, a specific type of supply chain management discusses the benefits that cooling provides to perishable produce and how it aids in preserving products for longer. Next, section 2.5, provides a brief history of the origin and variety of blueberries as well as a list of countries where this super-fruit is predominantly grown. Section 2.6 focuses on the growth and exportation of blueberries in specifically South Africa as well as the job opportunities that this industry creates.

Furthermore, the literature review discusses and illustrates a generic blueberry supply chain (section 2.7). In section 2.8, some of the main stages in a blueberry cold chain are discussed, namely harvesting, transportation, pre-cooling and cold storage (forced cooling). Furthermore, section 2.9 discusses the factors that need to be taken into consideration when looking at the effect that geographical location has on fruit quality, while section 2.10, discusses the appropriate time to harvest blueberries. The effect of handling and transportation methods on fruit quality is also covered (section 2.11). This chapter also defines temperature spikes and temperature breaks (section 2.12) in order to help the reader understand some of the parameters of a blueberry cold chain. Moreover, section 2.13 defines and discusses quality control and the different types of quality requirements needed to create a safe and hygienic environment. Lastly, the chapter concludes by highlighting some of the important information mentioned throughout this chapter.

2.2. Supply Chain

Various definitions for a supply chain have been developed over the years. These definitions vary in their level of detail and scope, but can all be related back to the same core principles (Du Toit & Vlok, 2014:26). The reason for this is because industries, organisations and even departments within the same organisation vary in terms of the inputs and outputs they produce and, therefore, vary in terms of their definition of a supply chain. For example, for some a supply chain is related to manufacturing, while for others it is about distribution and transportation or sources of capital and labour, etc. (Basu & Wright, 2008:3).

The Association for Operations Management (APICS) defines supply chain management as "the global network used to deliver products and services from raw materials to end consumers through an engineered flow of information, physical distribution and cash" (Ayers, 2006:5). Various sources mention that a supply chain is more than the physical movement of goods between two or more organisations and include the flow of information, movement of money, and the creation of intellectual capital. Therefore, Ayers (2006:5) defines a supply chain as "product life cycle processes comprising physical, information, financial and knowledge flows whose purpose is to satisfy end-user requirements with physical products and services from multiple, linked suppliers."

To better understand the supply chain, Wisner (2001) developed a diagram (**Figure 2.1**), which depicts the flow of information, products and knowledge within a supply chain. It emphasises the activities involved to transform raw materials into finished products. Furthermore, the diagram shows the parties involved in a supply chain and the interactive relationship necessary between each party to complete a successful supply chain. In addition, it attempts to highlight that each industry, organisation or product has its own supply chain and varies in its complexity, length and size. For example, a company that sells a single product most of the time only has one supplier and a small customer base as the product is specialised. Whereas a company selling multiple types of products will have multiple suppliers and customers. Thus, this company is bound to have multiple supply chains (Du Toit & Vlok, 2014:26). Therefore, Wisner (2001) reiterates the two definitions above by defining a supply chain as "a series of companies involved in making end-products available to customers. It includes all functions, processes, and activities involved in sourcing, making, and delivering the products or services to customers."

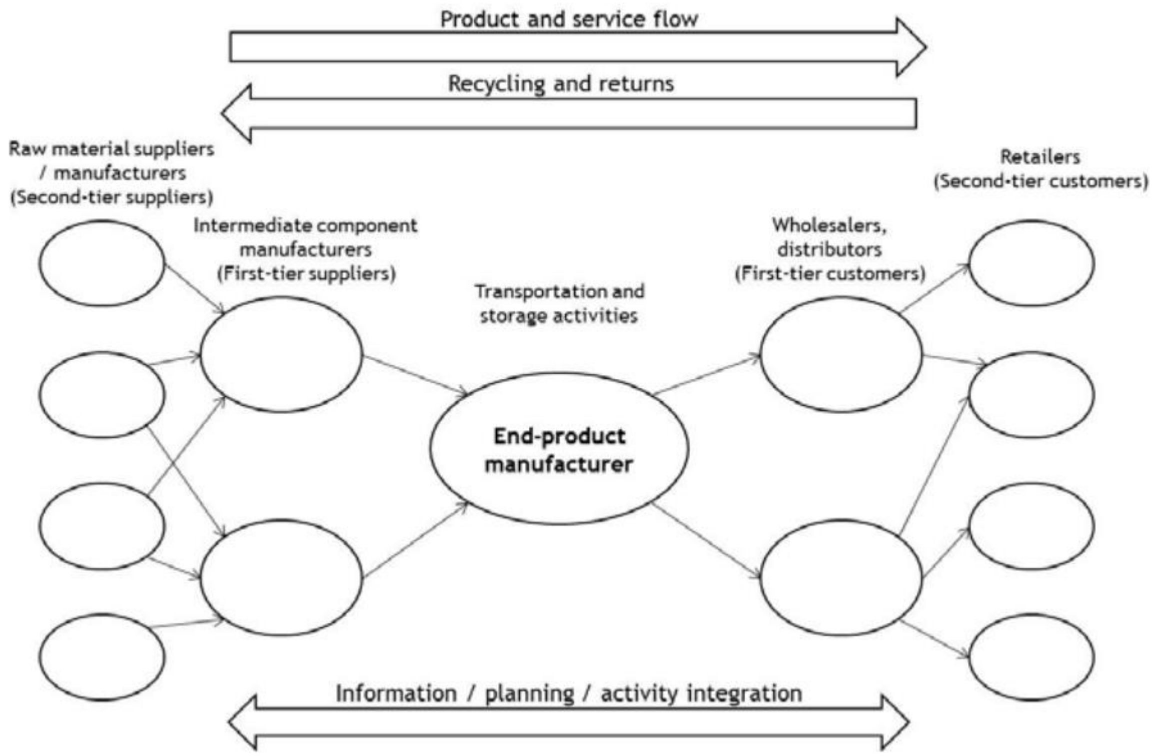


Figure 2.1: Generic supply chain adapted from Wisner (2001)
Source: Du Toit & Vlok, 2014:27

2.3. Supply Chain Management

As early as the 1980's an interest started to grow in the field of supply chain management as companies realised the added benefits of aligning and integrating with suppliers. This happened as companies identified the need to be more customer focussed by shifting the focus to be more productive, effective, and efficient (Du Toit & Vlok, 2014:27). Furthermore, external factors such as globalisation, the World Wide Web, business complexity and reduced barriers to international trade have increased the speed at which supply chain management is growing. To better understand supply chain management, the Council of Supply Chain Management Professionals (2021) mentions that there are two core principles to supply chain management, namely:

- For a product to reach its end consumer it requires the cumulative efforts of multiple organisations. Collectively, these organisations make up the supply chain.
- Supply chain management is the active management of supply chain activities. Supply chain management maximises customer value and creates a sustainable competitive advantage. These supply chain activities cover everything from product development,

sourcing, and production to logistics, as well as the information systems needed to coordinate these activities.

As with the supply chain, various definitions have been developed for supply chain management. The Council of Supply Chain Management Professionals (CSCMP) (2021) defines supply chain management as "the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers and customers. In essence, supply chain management integrates supply and demand management within and across companies" (Ayers, 2006:10). Wisner (2001) provides a more summarised definition and defines supply chain management as "the co-ordination and integration between supply chain partners participating in different activities related to products and services." Furthermore, Wisner (2001) states that the aim of supply chain management is to improve efficiencies, quality, and customer service through collaboration. Basu & Wright (2008:5) reiterates this by stating that one of supply chain management's objectives is to provide the best value to the customer by measuring, planning, and managing different links in the supply chain.

However, the notion that a supply chain is seen as a single integrated flow across the organisation is relatively new. The reason being that supply chain functions such as purchasing, planning, scheduling, manufacturing and distribution were traditionally seen as specialist functions that work separately. However, through supply chain management the flow of materials, information and knowledge across traditional barriers are made possible, causing the integration of these specialist functions (Basu & Wright, 2008:10). In essence, the effective integration of supply chain functions is seen as a good way to create value for customers (Du Toit & Vlok, 2014:27).

Du Toit & Vlok (2014:31) developed a detailed framework (**Figure 2.2**) to better understand supply chain management. The framework includes eight main components, namely: organisational strategy, supply chain policies, supply chain participants, supply chain life-cycle activities, supply chain support functions, performance measurements, continuous improvement, and supply chain management enablers. Each component was positioned in such a way to represent the position of the component in supply chain management as well as the relationship between these components. Furthermore, Du Toit & Vlok (2014:32) used arrows to show the flow between each component. **Figure 2.2** starts at the top with organisational strategy. What organisational strategy is and why your company needs it (2021) states that at its most basic, “an organisational strategy is a plan that specifies how a business will allocate resources (e.g. money, labour, and inventory) to support infrastructure, production, marketing, inventory and other business activities.” Organisational strategy flows into supply chain strategy, as these two components are normally aligned. Dittmann (2012) defines a supply chain strategy as “a formal written plan that details what actions the organization is going to take over a multi-year horizon.”

To achieve the above-mentioned strategies, good supply chain management procedures need to be implemented and followed. However, Du Toit & Vlok (2014:33) state that supply chain management consists out of three main components, namely: 1) supply chain participants, 2) supply chain lifecycle activities and 3) supply chain support functions. As seen in **Figure 2.2**, supply chain participants are connected to both supply chain management plans and supply chain life-cycle activities, but are more directly involved with life-cycle activities (Du Toit & Vlok, 2014:33). Furthermore, Du Toit & Vlok (2014:33) state that there is a many-to-many relationship between supply chain life-cycle activities and supply chain support functions. Performance measurement and continuous improvement is intertwined as one complements the other. As continuous improvement is not possible without something to measure performance against. In the end, the loop is complete as continuous improvement provides feedback to supply chain strategies and management before everything starts again. Lastly, supply chain management is not possible without the supply chain enablers as all the components in **Figure 2.2** are reliant on them, as they act across functions, activities, and participants (Du Toit & Vlok, 2014:33).

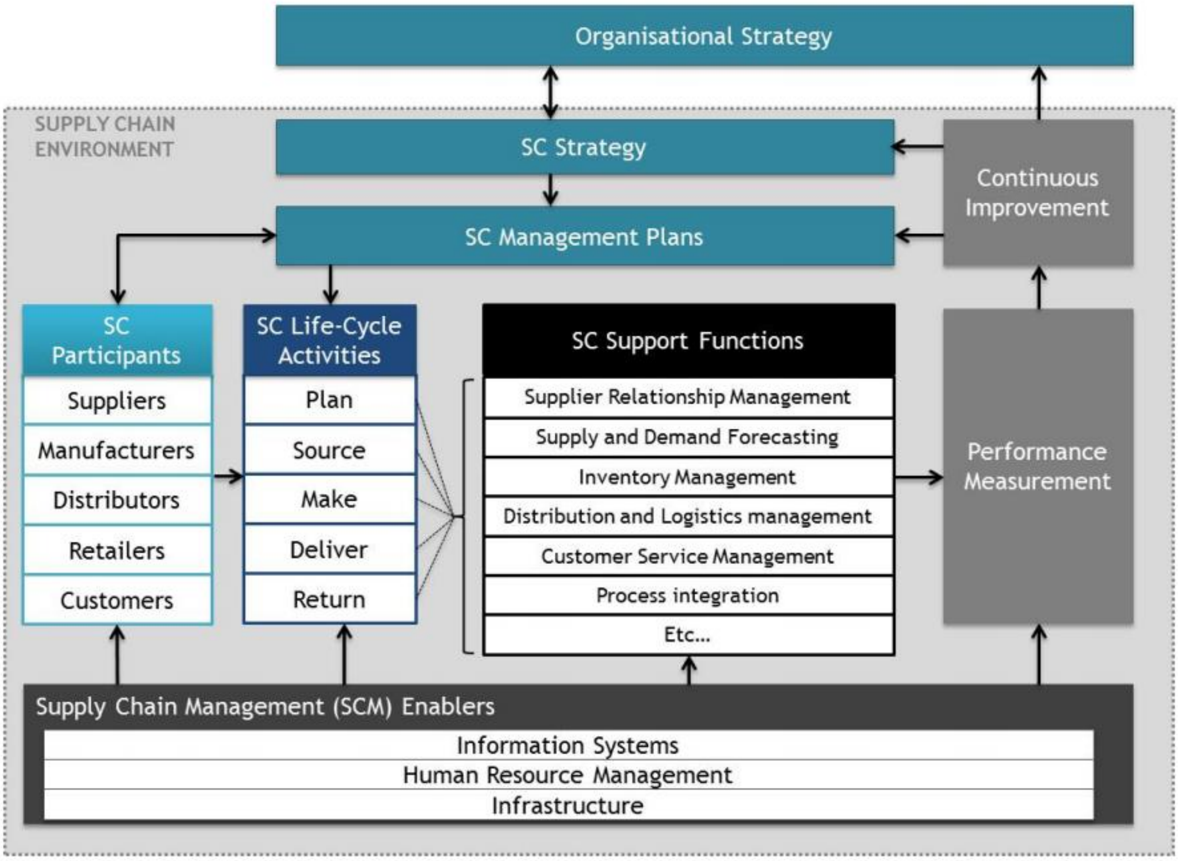


Figure 2.2: Supply Chain Management Framework
Source: Du Toit & Vlok, 2014:33

2.4. Cold Chain

Kitinoja (2013) and Ndraha, Hsiao, Vlajic, Yang & Lin (2018:13) define a cold chain as "the uninterrupted handling of perishable products within a low temperature environment in order to maintain the quality and safety of the products. Effectively, the cold chain starts with the postharvest steps of the value chain including harvesting, collection, packing, processing, storage, transport and marketing up until it reaches the final consumer." The planning and management of these role players is known as cold chain logistics. A continuous cold chain that is applied effectively ensures food safety, the prevention of waste and economic losses and that products arrive at the consumer without signs of deterioration (Elik, Yanik, Istanbullu, Guzelsoy, Yavuz & Gogus, 2019:30).

In developed countries, "cold" handling and storage systems are used to preserve perishable products and prevent possible food losses and it is seen as a necessity rather than an expense (Kitinoja, 2013). The International Refrigeration Institute (IIR) states that 23% of perishable foods go to waste due to developing countries not being able to make use of some sort of "cold" handling or storage systems (IIR, 2009). Furthermore, the IIR states that, in theory, if developing countries had the same cold chain protocols and refrigerated equipment at their disposal as developed countries, over 200 million tons of perishable produce would be preserved (James & James, 2010:1946).

The disposal of such large quantities makes sense as the ripening process of perishable produce continues even after it has been harvested. Therefore, perishable products continue to metabolise and consume their nutrients during packaging, distribution, marketing and sales (Kitinoja, 2013). Kitinoja & AlHassan (2010:35) and Ray & Ravi (2005:627) state that some of the main reasons for the disposal of fresh fruits and vegetables, as mentioned above, can be attributed to moisture loss, decay and bruising. These types of defects cannot always be prevented, however, by ensuring that an effective and efficient cold chain is maintained it can be minimized (Ahmad & Siddiqui, 2015:23). James & James (2010:1950) reiterate this by stating that refrigeration helps to maintain food quality as well as keep food safe by slowing down the rate at which changes occur in perishable produce. The refrigeration of perishable food should be continued during transportation, packaging and at the retailers to ensure an uninterrupted cold chain. **Table 2.1** shows the benefits that cooling provides to perishable horticultural foods, if it is maintained throughout the food cold chain.

Table 2.1: Benefits that cooling provides to perishable food

•	Reduces respiration - lessens perishability
•	Reduces transpiration - lessens moisture loss and shrivelling
•	Reduces ethylene production - slows ripening
•	Increases resistance to ethylene action
•	Decreases activity and growth of micro-organisms
•	Reduces browning and loss of texture, flavour, and nutrients
•	Delays ripening and natural senescence

Source: Adapted from Kitinoja (2013) and James & James (2010:1950)

The rate at which the natural degrading process of perishable products occur increases significantly as temperatures increase. To elaborate, in a study conducted by Kitinoja (2013), the rate of microbial growth and water loss, to name a few, doubled for each increase of 10°C. **Table 2.2** shows that as the temperature increased, the perishable produce tends to deteriorate at a faster rate, the relative shelf life decreases and the percentage loss per day increases. Hence, the importance of having an effective cold chain cannot be emphasized enough. However, Ndraha *et al.* (2018:19) mention that even if cooling methods such as "cold" handling and storing are used during the food cold chain, many factors can cause a fluctuation in the cold chain, which can have a devastating effect. These factors include bad cold chain practices, poorly designed refrigeration equipment and the position of products and packages in storage containers, among others (Ndraha *et al.*, 2018:19). Therefore, the continuous improvement of cold chain practises and procedures should always remain a major focus point when looking at perishable produce.

Table 2.2: Theoretical relationship between temperature, respiration rate and the deterioration rate of a non-chilling sensitive fresh commodity

Temperature °C	Assumed Q10	Relative velocity of deterioration	Relative shelf life	Loss per day (%)
0	-	1.0	100	1
10	3.0	3.0	33	3
20	2.5	7.5	13	8
30	2.0	15.0	7	14
40	1.5	22.5	4	25

Source: Kitinoja (2013)

2.5. Blueberry Industry

The South African Berry Producers' Association (SABPA) (2019) describes a blueberry as "a perennial flowering plant with blue- or purple-coloured berries". The blueberries' long road to success started in North America where blueberries were simply consumed and cultivated with no knowledge of the potential they possessed. However, after 40 years, the blueberry industry has revolutionised into an era of worldwide blueberry cultivation. Research and experiments have enabled farmers from around the world to plant and produce blueberry variations that suit a greater diversity of climates (Retamales & Hancock, 2018: vii). For example, initially the highbush blueberry cultivation was restricted to climates with more than 1000 chilling hours.

Nowadays, cultivars exist for subtropical and tropical environments that require no chilling hours whatsoever (Retamales & Hancock, 2018: vii).

Retamales and Hancock (2018:1) state that a large variation of blueberry cultivars exist, but mention that they all originate from three cultivars, namely the highbush blueberry, rabbit-eye blueberry, and the low-bush blueberry. The highbush blueberry can be grouped into northern, southern, and intermediate cultivar types. A well-drained, acidic soil with an abundance of moisture are requirements for all blueberry variations (Retamales & Hancock, 2018: 1). Climate also plays a significant role as variations of blueberry cultivars require different chilling hours. Blueberry cultivars are planted in terms of chilling requirements as well as their hardiness in winter. Therefore, temperature and the geographical location of plantations play an important role in the type and quality of blueberries produced.

According to Retamales and Hancock (2018:2), the southern highbush cultivar (SHBs) is predominantly grown in the USA, Australia, Argentina, Chile, Peru, Columbia, and southern Spain. The SHBs blueberry was imported to South Africa for the first time in the 1970's (Retamales & Hancock, 2018: 4). Due to its similar climate to the above-mentioned countries, the SHBs blueberry was able to adapt easily to the conditions. The SHBs blueberry requires chilling hours of less than 550 hours and do not tolerate winter temperatures below 0℃. This research is conducted using only the SHBs blueberry cultivar.

2.6. South African Blueberry Industry

During the 2019/2020 season, the total South African blueberry exports amounted to 12 282 tons (African News Agency, 2020). Although this industry is quite small compared to other local fruit industries such as the table grape and apple industry that export 200 000 and 300 000 tons respectively, the blueberry industry is quickly growing in importance, as the potential is endless (SABPA, 2019). The expected blueberry production for the 2020/2021 season is estimated at 25 000 tons (African News Agency, 2020). The four main production areas for blueberries in South Africa are the Western Cape with 60% of production, Limpopo accounting for 14%, the North-West with 10% and Gauteng accounting for 10%. The other 6% of production is split between the Free State, Kwazulu-Natal, and Mpumalanga provinces (Viljoen, 2018: 3). According to Horror (2018), the United Kingdom is the main market to which South Africa's blueberries are exported with an import value of R228 million. Other South African export regions include Europe, the Middle East, the Far East, and Asia (Viljoen, 2018, 14).

Figure 2.3 shows the growth of the blueberry industry since the 2014/2015 season. In the 2014/2015 season, a total of 1545 tons of blueberries were expected to be exported. The Perishable Produce Export Control Board (PPECB) stated that the final total for the season was 1792 tons. Although slow at the beginning, the expected increase in production for the 2015/2016 season was calculated at 39%. After the 2015/2016 season, the blueberry industry skyrocketed with an increase of 93% for the 2016/2017 season. Once again, the PPECB's final numbers showed that the actual volume of blueberries exported that season surpassed the expected amount. The 2017/2018 season was a slow season with an expected growth of only 33%. Although this increase in expected exports was much lower than the previous season, the industry remained optimistic, as an increase was still clear. As before, the PPECB confirmed that the actual volume of blueberries exported during the 2017/2018 season surpassed the expected amount with an end total of 6328 tons, 792 tons more than anticipated. The expected tonnage for the 2018/2019 season was estimated at 10 659 tons, an increase of 93%, which is a clear indication that the blueberry export industry is on an upwards trend in South Africa.

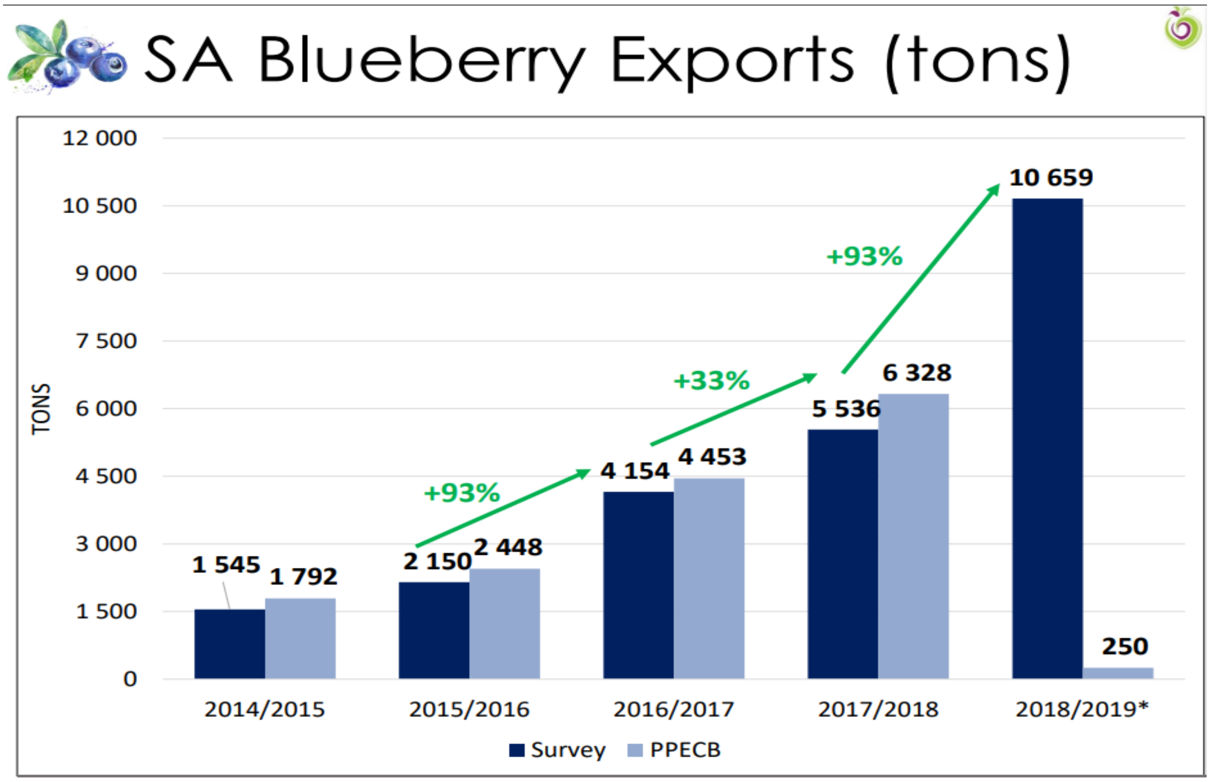


Figure 2.3: South African Blueberry Exports
Source: "Berry Industry Overview", 2018

An estimation done by the SABPA showed that the total area of blueberry production in 2017 was calculated at 1548 hectares. Hortgro (2018) states that, due to the fact that blueberries are a labour-intensive crop, it possesses the potential to create 2.96 jobs per hectare. That means that in 2017, roughly 4500 people had a job due to the blueberry industry and plans of increasing hectares are already taking place. According to Viljoen, (2018: 2), the expected hectares of blueberry production for 2023 are estimated at 3 169 hectares, which will provide jobs for roughly 9 300 people in total.

2.7. A Generic Blueberry Supply Chain

The increasing demand for large-scale production of fresh produce has prompted the horticultural industry to change the way they look at the handling and distribution of fresh produce. Mahajan, Caleb, Singh, Watkins & Geyer (2014) state that due to the fact that harvested produce is metabolically active, undergoing ripening and senescence processes, inadequate management of the cold chain can result in significant financial losses. The loss in quality or the outbreak of foodborne pathogens are only a couple of examples of the causes of an ineffective cold chain. It is, thus, clear that postharvest activities need to be controlled effectively. Luckily, new postharvest technologies have enabled the industry to better understand and manage these postharvest activities to deliver produce that have high nutritional and sensory quality (Mahajan *et al.*, 2014). Nevertheless, the blueberry industry is still new to South Africa and postharvest activities need to be examined carefully to effectively manage and improve the cold chain.

Figure 2.4 illustrates a supply chain of blueberries from harvest until it reaches the cold store. Starting from picking the blueberries and placing them into one-litre buckets. When the buckets are filled up, the pickers move to the quality control table where the buckets are emptied into crates. Here, inspection is performed whereafter the crates are labelled and stacked to be transported to the cold room. At the cold room, pallets are built and moved to the pre-cooling room. After pre-cooling is sufficiently applied, the pallets are transported to the pack house. Here inspection takes place and pallets are placed in a cold room awaiting sorting and packaging. Thereafter, the pallets get inspected by the PPECB and placed in the cold room, awaiting transportation to the cold store where forced cooling will be applied.

Figure 2.4: Blueberry Export Cold Supply Chain
Source: Created by the author for the purpose of this study

2.8. Blueberry Cold Chain

Mercier, Villeneuve, Mondor & Uysal (2017) define a cold chain as "the succession of refrigeration steps along the supply chain that are applied to keep perishable food in the desired temperature range." Fresh Food Trade SA (2018) states that berries are seen as perishable produce that need to be forced-air cooled within six hours after harvesting to a temperature of 0ºC. Due to berries being very delicate fruit, the cold chain must be applied strictly, as the cold chain can decelerate the biological decay processes and ensure safe and high-quality produce. A variation in temperature along the cold chain also known as a "temperature spike" can result in condensation of moisture, which increases decay, and can result in the growth of pathogens and spoilage microorganisms. The worst scenario would be that due to the break in the cold chain the produce becomes inedible, which could cause foodborne illnesses if consumed (Mercier *et al*., 2017).

According to Mercier *et al.*, (2017), refrigeration, food safety, and food wastage are intimately linked. Mercier *et al.*, (2017) found major weaknesses in the modern cold chain. These weaknesses include pre-cooling, ground operations during transportation, storage during display at retail and in domestic refrigerators, and commercial handling practices (Mercier *et al*., 2017). **Figure 2.5** illustrates the main steps in a typical cold chain. For this study, the entire cold chain was not under investigation. As indicated in red, specific focus was placed on harvesting, land transportation, pre-cooling and cold storage (forced cooling). The goal is to identify whether these weaknesses also exist within the blueberry cold chain, and if so, what can be done to improve them in order to reduce fruit wastage and improve fruit quality.

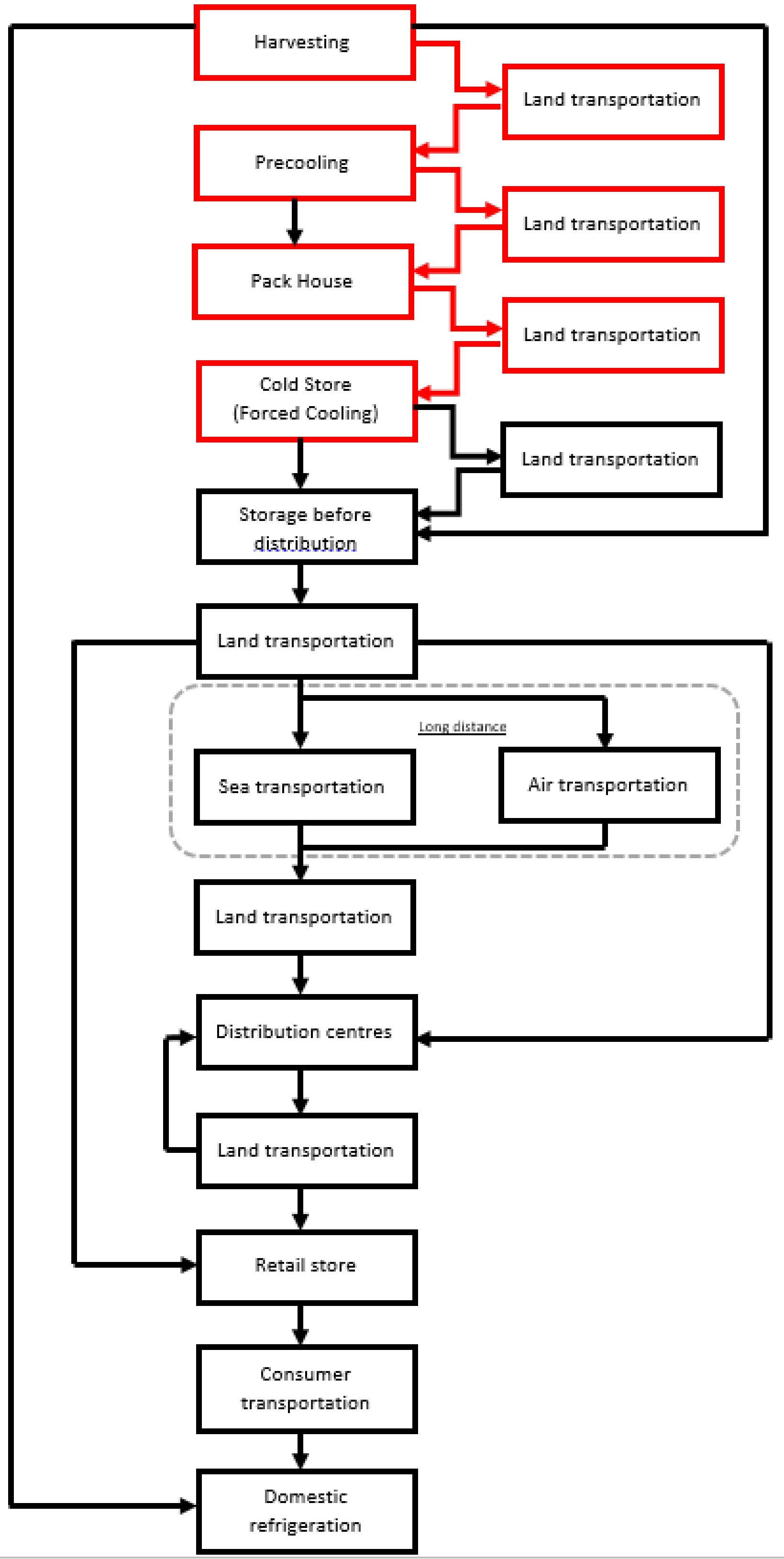


Figure 2.5: Overview of the main steps in a typical cold chain
Source: Adapted from Mercier, Villeneuve, Mondor & Uysal, 2017

2.8.1. Harvesting

Although the cold chain technically only starts as soon as pre-cooling is implemented, a few factors could contribute to the cold chain being more efficient during the harvesting phase. Mercier *et al.,* (2017) found that the temperatures of produce being harvested are often very high. Harvesting during the early morning, while temperatures are still low, could contribute to temperatures dropping faster when pre-cooling is applied. However, Cold Chain Specialist (2019) states that this is not a realistic goal in South Africa as a large number of blueberries would go to waste if farmers were only allowed to harvest during the early mornings. Cold Chain Specialist (2019) mentioned that table grapes are used as the benchmark to better understand the blueberry cold chain. Therefore, after various discussions with blueberry experts, it was determined that blueberries may not be harvested in temperatures of 30ºC or higher and would be recorded as a breach of protocol. Furthermore, emphasis should be placed on empty buckets and crates that lie in the sun before or during usage, as the warm exterior of the buckets and crates could contribute to a rise in temperature of the blueberries.

Chu, Gao, Chen, Fang & Zheng (2018) found that harvest and post-harvest handling were the two main reasons that caused the loss of bloom wax on blueberries. Van Hoorn (2004) supports this claim by mentioning that rough handling and holding the blueberries in one’s hand easily removes bloom wax. The loss of bloom wax has a direct influence on a shortened shelf-life. It also accelerates the loss of water and reduces the nutritional qualities while increasing the decay of blueberries (Chu, Gao, Chen, Fang & Zheng, 2018). Supervisors, the person in charge of a team of pickers, and pickers should be educated about the size, colour, firmness and handling of blueberries and the effect that they have on the cold chain.

Greeff (2003) states that the ripening time span for all blueberry cultivars is between four to six weeks from the first blueberry fruit to the last. Blueberries must be harvested at the 100% blue stage for domestic markets or when being airfreighted. When blueberries are to be exported by deep-sea transport, they should be harvested at the 85% to 90% stage (Cold Chain Specialist, 2019).

Peano, Giacalone, Gonzalez, Beccaro, & Bounous (2002) mention that when over mature blueberries are harvested, they are more easily damaged, lose their firmness at a rapid pace and are more susceptible to fungal decay. In contrast, when blueberries are harvested pre-mature, the evolution of favourable organoleptic traits can no longer evolve (Giacalone, Peano, Guarinoni, Beccaro, & Bounous, 2002). Therefore, it is of vital importance to harvest at the correct time as pre-mature harvesting could compromise the taste of blueberries whereas over mature harvesting reduces the storage potential of blueberries (Peano *et al*., 2002).

Harvesting blueberries at the right maturity also reduces the handling of the blueberries when they arrive at the quality control (QC) table and, will therefore, preserve the bloom wax on the blueberries. Quality control personal should make sure that all standers are met when the fruit arrives at the QC tables. According to Van Hoorn (2004), the criteria for grading for international markets include size, presence of bloom and the absence of blemishes and bruises. For the EU and UK, a berry must be larger than 12mm, but specifications include different size brackets. It is recommended that QC tables and harvested produce should be kept in the shade while waiting for transportation to the pack house as direct sunlight could increase the pulp temperature of the blueberries more rapidly. Van Hoorn, (2004) states that trays left in the shade have a temperature of 5-6ºC lower than the ambient air temperature.

2.8.2. Transportation

Freiboth, Goedhals-Gerber, Van Dyk, & Dodd (2013) state that cold chain logistics was developed to preserve the quality of perishable products rather than improving the quality of these products. James, James, & Evans (2006) also refer to preserving the temperature in cold chain logistics, but focus specifically on transportation. They mention that refrigeration systems of reefer containers are not designed to lower the temperatures of produce, but rather to preserve temperatures during transit. Boyette *et al*., (1993) support this claim by mentioning that refrigerated transport provides little to no additional cooling. Sarıbardak (2020), state that failure to keep perishable produce at their designated temperature during transportation can result in microbial growth, degradation, discolouring and an overall decrease in fruit quality that will have a direct effect on the value of the fruit.

Boyette, Wilson, & Estes (1989) developed a few guidelines that enable transporters of perishable produce to contribute to the cold chain. They mention that trailers should be pre-cooled before being loaded, especially during warm days. However, a study done by Freiboth *et al*., (2013) found that a truck should not be pre-cooled unless an airlock is used at the loading bay. In the absence of an airlock, the warm air from outside causes moisture to condensate in the truck as soon as the doors are opened for loading and can cause considerable damage to the fruit. This phenomenon is known as container rain. It is recommended that each section in the cold chain where transportation is involved should be equipped with an airlock-system and loading bay. Boyette *et al*., (1989) also mention that transporters should take responsibility by ensuring that the trailers and refrigeration units are up to standard and in good condition. Furthermore, they encourage transporters to measure product temperature during and after loading. Lastly, transporters should make sure that the produce are always transported at the temperature prescribed by the client. In the case of Company X, blueberries should be transported at 6˚C.

With the continuous development of technology, transport and logistics companies are able to provide accurate and real-time data on where the trucks are (GPS based tracking) and what the ambient temperature and relative humidity inside the trucks are (wireless sensors) at any given moment (Sarıbardak, 2020). In addition, the wireless sensors work in tandem with cloud-based tracking software that can alert drivers and logistical companies when there is a deviant of temperature or humidity during transportation (Sarıbardak, 2020). Ultimately, this will contribute to a more effective and reliable transportation leg in the cold chain of perishable produce.

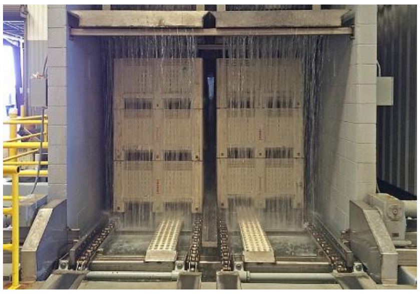
2.8.3. Pre-Cooling

During harvest, the temperature of the blueberries is the same as that of the environment from which it is harvested, thus, carrying a substantial amount of heat upon arrival at the coldroom. This high product temperature is also known as field heat. It is important to attempt to harvest when ambient temperatures are low, as it is well-known that temperature is the main environmental contributor to the deterioration of freshly harvested produce (Mishra & Gamage, 2007:50). This is due to the fact that respiration rates rely on temperature, since high temperatures increase the rate of respiration (Elansari, Fenton & Callahan, 2019:162). James, James & Evans (2006) state that after harvesting perishable produce, the rapid extraction of heat from the produce, referred to as pre-cooling, is critical to remove unwanted field heat. The main goal of pre-cooling is to ensure a rapid decrease in the temperature of a product in product specific conditions, within a certain time period, given the space provided (Elansari, Fenton & Callahan, 2019:163). A well-designed pre-cooling system is equiped with sufficient refrigeration, to ensure an efficient transition in product temperatures. Furthermore, Elansari *et al.*, (2019:161) state that the pre-cooling process should start immediately after harvest, as field heat accelerates the deterioration and senescence processes such as water loss, wilting and shrivelling. Ladanyia (2008:319) reiterates this by stating that “prompt pre-cooling slows or inhibits the growth of decay caused by microorganisms (mould and bacteria), restricts enzymatic degradation and respiratory activities (softening), slows or inhibits water loss (wilting), and reduces ethylene production (a ripening agent) or minimizes the product's reaction to ethylene". Therefore, pre-cooling can contribute to the preservation of quality and an increased shelf life. It is, thus, important that pre-cooling is applied effectively, as insufficient pre-cooling could lead to a rise in temperature further along the cold chain.

When identifying a pre-cooling method, several trade-offs can occur in the search to find the most suitable method for each specific product. Mishra & Gamage (2007:54) identified the following parameters when selecting an appropriate pre-cooling method: 1) the nature of the produce (*e.g. product characteristics*, *amount*, *chilling sensitivity*), 2) temperature of the produce at the time of harvest (*e.g. identifying acceptable final temperature*), 3) cooling time required, 4) product throughput, 5) type of packaging used, 6) desired storage life, and 7) other considerations (e.g. *comparative energy efficiency, availability, market requirements, scale of the operation, and associated capital and operating costs*). If incorrect pre-cooling methods are identified it can lead to an ineffective cold chain, which in turn can cause rejection of the products. When pre-cooling is applied, heat is removed from the products through the means of a cooling medium such as water, air or ice. **Table 2.3** summarises the five most common pre-cooling methods, as well as the cooling medium used by each method. For this study, pre-cooling at the cold room on the farms was applied at 6ºC, prior to the blueberries being transported and packed into pallets at the pack house.

Table 2.3: The five most common pre-cooling methods used to remove field heat

Pre-Cooling Method	Description	Visual Presentation
Room cooling	This involves placing crops in a cold room for it to cool passively, where cold air passing through a fan serves as the refrigeration unit. This method has low cost involvement, but can result in slow cooling rates.	

Forced-air cooling	Cold air is rapidly pulled through the bins or cartons at high velocity. This method increases the rate of cooling and avoids condensation. The main disadvantage is the risk of desiccation of the crop.	
Top or liquid icing	Ice is used to cool down the product, which is packed in boxes. Crushed ice can also be placed directly on top of the crop. This method is used for products that are not susceptible to freezing, as ice can cause freezing injuries.	
Hydro-cooling	This method can either be a continuous feed on a conveyor or a batch treatment. Products may be drenched by a shower or immersed in a dipped tank of cold water. A heat exchanger is necessary to maintain the water temperature. This method permits faster cooling, it helps clean the produce, and if the water is chlorinated, the method can prevent spoilage of the crop. It is important to include a sanitiser to avoid spreading human or plant pathogens. This method is used mainly for pre-cooling vegetables.	  

Vacuum cooling	This method is used for crops that do not have a thick wax cuticle. Crops are rapidly cooled down due to the evacuation of the air, which causes a rapid evaporation of water located on the surface of the crops. A disadvantage of this method is the reduction in crop weight of 1% for every 5°C or 6°C reduction in temperature.	

Source: Table adapted from Dumont, Orsat & Raghaven, 2016:137

Lastly, pre-cooling is seen as an essential part of the cold chain and adds an element of marketability, as not all farmers can afford to install such equipment and facilities. Since pre-cooling reduces the respiration rate of produce, pre-cooling provides more market flexibility as it increases the window in which the produce can be sold (Elansari *et al.*, 2019:163). It is noteworthy to mention that pre-cooling would be in vain if temperatures are not kept in line with the temperatures set out in the protocols of Company X. In order to maintain an effective cold chain, pre-cooled pallets must be placed in a cold room while awaiting transportation to the pack house. Furthermore, during pre-cooling, it is especially crucial that pre-cooling is applied to reach the desired temperature, as refrigeration systems of reefer trucks are generally designed to preserve the temperature of produce rather than lower the temperature.

2.8.3.1. Pre-cooling method applied (Forced-air cooling)

Forced-air cooling was the preferred pre-cooling method applied on all the farms throughout the study. It is a more advanced type of room cooling where air is forced through the produce inside the crates, therefore, effectively increasing the surface area being pre-cooled, as illustrated in **Figure 2.6**. A major advantage of forced-air cooling is that it drastically reduces the cooling time (by ten times or more) compared to the conventional room cooling method. It is important to mention that the only governing factor during forced-air cooling, is the velocity of the refrigerated air being forced through the produce (Elansari *et al.*, 2019:170).

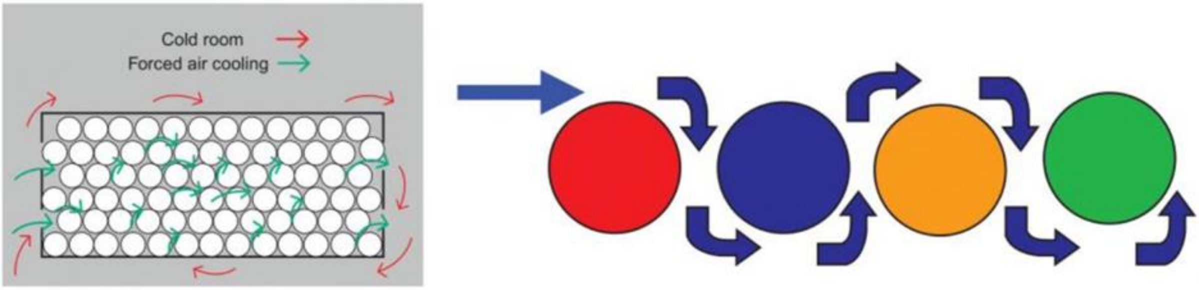


Figure 2.6: The airflow in a pallet of room cooling compared to forced-air cooling
Source: Elansari *et al.,* 2019:170

When using forced-air cooling as a pre-cooling method, the refrigerated air around the system should be constantly monitored, as chilling injuries or freezing injuries are a common occurence if not monitored. Elansari *et al.,* (2019:171) state that forced-air coolers make use of fans in order to suck the warm air out of the crates, transform it to cold air and release it back into the pre-cooling room around the system (**Figure 2.7**). In order for forced air cooling to have the desired effect, it is important to determine the required airflow rate as well as the pressure required before the selection and installation of the fans. The following criteria will help to determine the specific requirements of the fans; *1) Produce type and productivity of the system 2) arrangement applied (bulk, pallets, crates) 3) cooling rate designed* (Elansari *et al.,* 2019:175). For this study, the produce type was blueberries, with crates arriving at the cold room every half hour. The arrangement was crates stacked as a pallet, while the cooling rate designed was forced-air cooling. Various airflow configurations for forced-air cooling are available such as cold wall, serpentine flow and tunnel cooler, to name a few. All the farms except Farm F made use of the cold wall forced-air cooling system (**Figure 2.8**). To be more specific, the forced-air pre-cooling system used on Farms A, B, C, D and E were a dry-coil, high humidity forced-air pre-cooling system working with a direct expansion (DX) refrigeration system and a cold wall airflow configuration (Elansari *et al.,* 2019:175). Farm F made use of a portable forced-air pre-cooling unit. As shown in **Figure 2.9** these units are built into a container, which makes the mobility easier if needed.

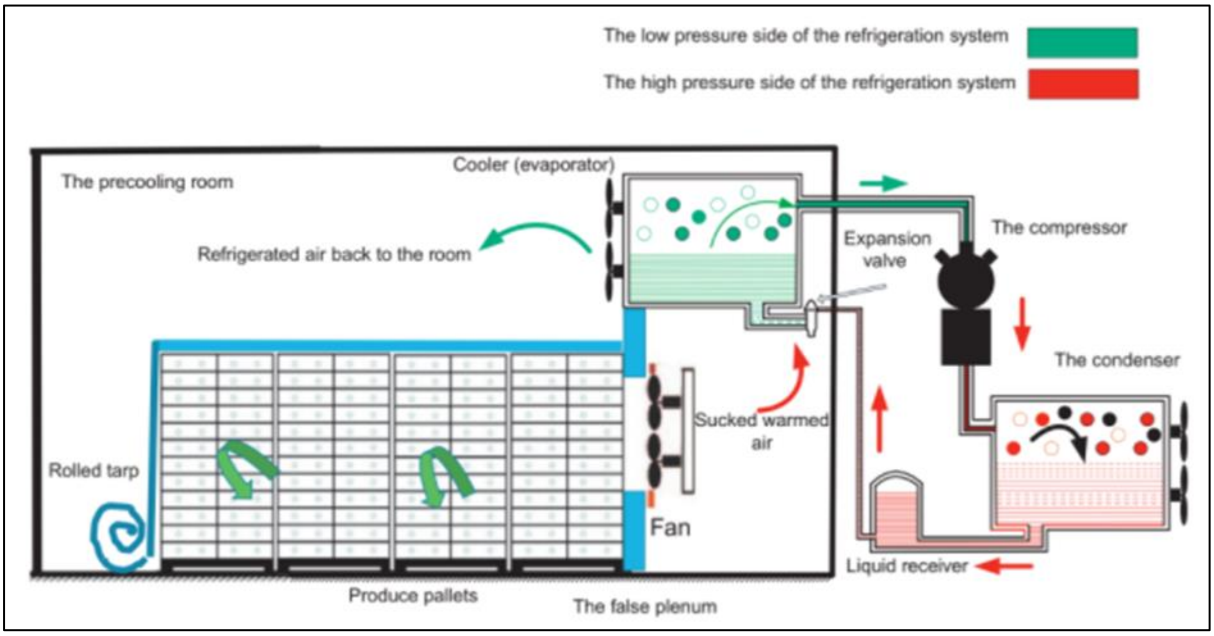


Figure 2.7: Dry-coil high humidity forced-air pre-cooling system working with a DX refrigeration system
Source: Elansari *et al.*, 2019:179

Figure 2.8: Forced-air pre-cooling systems used on Farms A, B, C, D and E
Source: Images taken by the researcher during the study

Figure 2.9: Portable forced-air pre-cooling systems used on Farm F
Source: Images taken by the researcher during the study

2.8.4. Cold store (Forced cooling)

According to Boyette *et al.*, (1996), blueberries continue to respire and produce heat after harvest. Therefore, pre-cooling plays an important role before packaging, as it reduces the respiration rate and delays the decline in quality. However, for cooling to be effective in the cold chain, it must be thoroughly and consistently applied. Boyette *et al.*, (1996) states that a cold chain will only be effective if forced cooling is applied, as the effectiveness of cooling and not its availability, is the deciding factor in quality. Forced cooling is applied after pallets are packed. Cold rooms do not possess the capability to penetrate through the packaging to lower temperatures in the same time span as forced cooling, and are, therefore, not as effective. Although forced cooling is much quicker, proper control is important, as blueberries freeze at approximately -2°C (Boyette *et al.*, 1996). Chilling injuries can be as devastating to blueberries and high temperatures and should be avoided. Blueberries have a maximum storage life of two to three weeks. However, if the correct cold chain protocols are not followed, a blueberry's life span will be a lot shorter as they are known to have a high level of perishability. The optimum storage temperature of blueberries is between 0-1°C, while the perfect humidity conditions are a relative humidity of 90-95% (Company X, 2020). For Farms A, B and C forced cooling was applied in facilities that were located at the same location as the pack house. Whereas with Farms D, E and F, the pallets had to be transported to the forced cooling facilities. Forced cooling was applied on all the pallets using a tunnel cooler airflow configuration (**Figure 2.10**). This configuration is the most common airflow configuration used for forced-air cooling. Two rows of pallets are stacked against each other beginning against a wall with a fan in the middle. At the end of the row, two more pallets are used to close the gap between the pallets (**Figure 2.10**). A tarpaulin is thrown over the pallets while the holes at the bottom are covered to ensure that air flows through the cartons or crates (Elansari *et al.,* 2019:171). As with pre-cooling, the air in the cold room is chilled to ensure that cold air is forced over the produce. When the fan is switched on, cold air gets pulled to the gap in between the pallets. The warm air from the produce is then absorbed by the fan, which turns it into cold air by means of a refrigeration coil.

Figure 2.10: Forced-air cooling with a tunnel cooler airflow configuration
Source: Images taken by the researcher during the study

2.9. Geographical Location of the Fruit Farms under Investigation

Research conducted on Fuji apples by Zhang, Zhou, Li, Wei & Han (2018) showed that various factors need to be taken into consideration when looking at the effect that geographical location has on fruit quality. These factors include genetics, proper pollination, environmental conditions, harvest methods and condition and physiological age of the fruit at harvest (Alves and Coêlho de Lima, 2011:374). Specific focus is placed on environmental conditions during harvest such as different climate factors, for example, temperature, light, rainfall, relative humidity as well as seasonal trends. Focus is also placed on harvesting methods in terms of the way fruit are handled as well as their efficiency.

According to Kader & Rolle (2004), the location of production can determine the ascorbic acid, carotene, riboflavin, thiamine, and flavonoid contents that the plant absorbs. Geographical location of the three farms in the Western Cape used in this research are spread out over the Wolseley, Wellington, and Robertson districts. These farms are referred to as Farm A, B and C. The farms were chosen to compare different areas within the Western Cape with one another. All three farms are roughly (Farm A – 110km, Farm B – 120km and Farm C – 43km) away from Pack House 1, which also functions as a cold store and is situated in the Robertson district. The other three farms are situated in Gauteng. Farm D is situated close to Magaliesburg, Farm E is situated in the Moddersprruit district and Farm F is situated in the Mooinooi district. All three farms are roughly 140km from Pack House 2, where after finished pallets need to be transported to Cold Store 2 to receive forced cooling. Cold Store 2 is 5.6km from Pack House 2.

Another reason why the farms above were chosen for the study is that each farm uses different pre-cooling systems at their farms. This provides insight in terms of which cooling system is the most effective. In addition, each farm uses different harvesting methods, which were investigated.

2.10. Time of Harvest

Kader *et al.,* (2004) found that management responsibilities include identifying the correct time of harvest in relation to the products maturity as well as climatic conditions. Harvesting can last days or even weeks depending on whether the blueberries are at the right maturity. Greeff (2003) states that the ripening time span for all blueberry cultivars lasts between four to six weeks from the first blueberry fruit to the last. According to Eck *et al.,* (1990) blueberries are picked when they reach the 100% blue stage. Company X created colour cards, for each of their blueberry varieties, in order to ensure the maturity of their fruit. Sugar tests (brix) as well as firmness tests (durofel) are used to verify the maturity of the fruit. These tests also determine to which export markets the blueberries will be delivered to (Cold Chain Specialist, 2019). Kader *et al.,* (2004) state that storage-life and quality are both determined by the maturity of the fruit. Shrivelling and inferior flavour are both signs that the fruit was harvested prematurely. In the case of the fruit being overripe, signs of the fruit becoming soft, mealy and flavourless will be evident not long after harvest (Kader *et al.*, 2004).

According to Kader *et al.,* (2004) the quality of fruit is greatly impacted by climatic factors including temperature and light intensity. Both elements are ever changing as the season changes. Therefore, the ascorbic acid, carotene, riboflavin, thiamine, and flavonoid contents that the plant absorbs are influenced by, not only the location of production, but also the season in which the fruits are grown. For example, low light intensity causes the ascorbic acid content of plant tissues to be low. Furthermore, high temperatures cause transpiration rates to increase and directly influence the uptake and metabolism of mineral nutrients by plants (Kader *et al.*, 2004). It is, thus, of vital importance to strategically select the time of planting as well as time of harvest.

Mercier *et al.,* (2017) found that the temperatures of produce being harvested are often very high. Cold Chain Specialist (2019) states that harvesting mostly occurs during the morning hours or during the day depending on the weather. Therefore, Company X strives to not harvest blueberries when temperatures exceed 30°C. Rainfall also plays a significant role in the blueberry industry as it affects water supply to the plant, which may influence the composition of the plant (Kader *et al.*, 2004). Due to the decay that rainfall or even dew causes, Company X strives to not harvest or handle blueberries while moisture is evident on the blueberries (Cold Chain Specialist, 2019.)

2.11. Handling Methods and Transportation Systems

According to Jedermann, Nicometo, Uysal & Lang (2014), the growing world population is creating a need for better management of cold chain inefficiencies of perishable produce along the food supply chain in order to eliminate perishable waste. Various factors play a role in the deterioration of perishable produce and can be found in any part of the supply chain, especially with regard to temperature management. According to Vigneault, Thompson, Wu, Hui & Leblanc (2009), transportation is one of the major causes of deterioration. Jedermann *et al.*, (2014) state that temperatures are rarely held under optimal product-specific values during transportation. Vigneault *et al.*, (2009) agree that temperature-controlled containers could reduce spoilage from 40% to 5% if applied according to regulations.

However, if the initial quality of produce is not up to standard, adequate transportation will not make a difference. Therefore, another reason for unnecessary losses of shelf life is due to careless handling methods. Harvest as well as post-harvest standards are not met, as farmers do not effectively monitor many of the commodities. For example, farmers do not efficiently pre-cool after harvest (Jedermann *et al.*, 2014) or make sure that produce is free of mechanical damage or other conditions (Vigneault *et al.*, 2009).

This study looks at the different handling techniques for loading, offloading and transporting blueberries from the farm to the centralised pack house. Although all six farms harvest their blueberries by hand, different technologies are used to pre-cool their blueberries. On three of the farms, the blueberries are transported to a centralised pack house where the blueberries are packaged and then transported to a centralised cold store. Whereas the remaining three farms only transport the blueberries once, as the pack house and the cold store are situated at the same location.

2.12. Temperature Spikes and Temperature Breaks

Freiboth *et al*., (2013) state that a perpetual temperature profile is known as "an uninterrupted series of refrigerated production, storage and distribution activities, which maintain a desired low temperature range." Although all companies strive towards a perpetual temperature profile, the reality is that very few achieve this. When cold chains are not properly maintained or inadequate protocols are being followed, temperature spikes or even worse, temperature breaks can occur. Thompson (2002) states that each perishable product has a product-appropriate set point and the rise in temperature above this set point has a negative effect on the quality of perishable products.

It is important to note that each product reacts in a unique way to temperature, and therefore, has its own product-appropriate set points. Furthermore, the product-appropriate set point is determined by the protocols being applied at each stage of the cold chain. To elaborate, the product-appropriate set point is not the same when pre-cooling is applied compared with when forced cooling is applied. That being said, the definition for a temperature break also differs for each product as some products are more susceptible to temperature than others.

The blueberry industry is relatively new and due to the high competitiveness of the industry information regarding the cold chain is either outdated or kept confidential. After discussions with various experts in the industry, it was identified that table grapes are used as a benchmark to better understand and improve the blueberry cold chain. Freiboth *et al.*, (2013) define a temperature break in the table grape industry as "any rise in temperature of 2°C, for longer than 90 minutes". Furthermore, they mention that when the temperature falls below -1.5°C for longer than 90 minutes it has the same negative effect due to chilling injuries. Blueberry Grower (2020) mentions that although blueberries are similar to grapes, they are more susceptible to a fluctuation in temperature than table grapes.

After consultation with various experts in the blueberry and cold chain industries, the following definition was identified. A temperature break in the blueberry industry is defined as "any rise in temperature of 2°C above the product-appropriate set point, for longer than 30 minutes." Furthermore, when the temperature falls below -1.5°C for longer than 30 minutes, it can be seen as chilling injury. The reasoning behind this is that blueberries freeze at approximately -2°C (Boyette *et al.,* 1996). Lastly, when the temperature rises above the established 2°C or falls below the -1.5°C barrier, but does not last longer than 30 minutes, it is defined as a temperature spike and not a temperature break. Recurring temperature spikes can be just as harmful to the fruit as one long temperature break.

2.13. Quality Control

Faria-Fernandes, Filho & Bonney (2009) define quality control as "the function that aims to measure and improve the production and marketing processes, as well as the product and information flow to provide products according to specification". In the fruit industry, quality control is a broad concept, since it involves a wide range of factors such as product quality, timely delivery, communication, and customer satisfaction among others (Jraisat & Sawalha, 2013). Kimball (1991) states that the quality control department of a company can be divided into three main parts. The first part involves the measurement and control of the product. This is accomplished by comparing the product to specific parameters as set out by the company. Normally, these parameters are developed to comply with exporting standards, reach specific goals, or to ensure that the product aligns with the policies set out by the company. Kimbell (1991) mentions that when specific focus is placed on ensuring that the product achieves a high-quality standard, it is referred to as quality assurance rather than quality control. Quality assurance goes beyond only the measurement and reporting of inconsistencies and tries to identify which areas can be improved on to eliminate these inconsistencies.

The second role that the quality control department plays, is to ensure that both the environment and product are clean and free from contamination (Kimball, 1991). A study conducted on dates in the Gulf Cooperation Council (GCC) countries of the Arabian Peninsula by Kader & Hussein (2009:13) found that various natural contaminants exist such as fungal and bacterial toxins, heavy metals, environmental pollutants, residue of pesticides and microbial contamination. Kader & Hussein (2009:13) state that microbial contamination is deemed as the biggest safety risk by professionals. It occurs when food has been contaminated by microorganisms, including bacteria, viruses, mould, fungi, and toxins. It is the most common reason behind outbreaks of food poisoning. In Module 8: Food contamination and spoilage (2017), a study conducted in Ethiopia, identified eleven routes through which microbial contamination can occur. These routes are: 1) air and dust, 2) soil, water, and plants, 3) gastrointestinal tract, 4) animals, 5) animal feeds, 6) food handlers, 7) food utensils, 8) cross-contaminations, 9) unsafe temperature, 10) poor personal hygiene and 11) pests. The best way to prevent these types of contamination are to follow strict, high standard food hygiene practices (Collier, 2019). Kader & Hussein (2009:13) reiterate this and further mention that the risk of microbial contamination can be drastically reduced by applying "Good Agricultural Practices" during production and harvest and "Good Hygienic Practices" during any stage of handling food. The "Good Agricultural Practices" (GAPs) and "Good Hygienic Practices" (GHPs) applied on the date farms of the Arabian Peninsula addressed the following issues:

1. *Water quality:* Clean, healthy water should be used to irrigate the plants. If irrigated with water containing human waste, the risk of pesticides and the contamination of foods increases drastically.

2. *Manure and municipal biosolids:* Organic fertilizers, such as chicken manure, should be sterilized before being used on orchards to avoid the risk of contaminating the food that comes into contact with the soil. This prevents the risk of *Salmonella*, *Listeria*, and other pathogens.

3. *Worker health and hygiene:* Personnel hygiene to prevent the spread of illness. Ill workers should not be allowed to work with food; water for drinking and washing of hands should be easily accessible; toilet facilities with handwashing stations should be provided; employees should be educated on the importance of good hygiene and emphasis should be placed on worker sanitation.

4. *Field and packing facility sanitation:* Any surface that encounters food should be cleaned and sanitised regularly. These surfaces include harvest containers, equipment, utensils, tables, etc.

5. *Sanitize storage facilities, transportation vehicles and distribution centres regularly and avoid cross-contamination:* Storage rooms, transportation means and distribution centres must be thoroughly cleaned after every shift to remove any possible residues from previously stored produce and conventionally produced foods. Furthermore, employees should be educated on the dangers of cross-contamination.

6. *Traceback:* Traceability from the supermarket back to the origin of the produce is important. If diseases do occur, traceback will help to possibly identify the area of concern and immediately stop the process to avoid further damage (Kader & Hussein, 2009:13).

Figure 2.11 shows some of the products and GAPs and GHPs implemented to ensure a hygienic and safe work environment. Each role player in the beginning stages of the blueberry supply chain is responsible to keep their own environment clean and free from contamination.

The third and final role of the quality control department is management, which includes the management of protocols, personnel, policies, etc. (Kimball, 1991). It is important to mention that management here, specifically refers to the management of ensuring the successful delivery of a high-quality product.

Figure 2.11: Products and protocols implemented to ensure a hygienic work environment
Source: Images taken by the researcher during the study

2.14. Conclusion

The existing literature provided the researcher with a better perspective of the current status of the South African blueberry industry, more specifically, how a conventional blueberry supply chain functions at present. Furthermore, the literature review discussed the importance of good cold chain practices and identified numerous factors that could have an influence on fruit quality. In addition, the importance of good hygiene and quality control practices were highlighted. This chapter showed that various questions regarding the South African blueberry industry remain unanswered, mainly due to the competitive nature of this industry and the unwillingness of those involved to share information.

Chapter 3: Research Design and Methodology

3.1. Introduction

To help the researcher identify and explain the different components forming part of the study, the researcher made use of the research onion (**Figure 3.1**) developed by Saunders, Lewis & Thornhill, (2016). To identify the appropriate research design and research methods, a specific research philosophy and approach needed to be adopted (Saunders *et al*., 2016). This is important, since a research philosophy contains assumptions that influence the research design. Furthermore, the research philosophy and approach have an influence on how the research questions are answered by the researcher (Saunders *et al*., 2016). The chapter mentions how both primary and secondary research were used to collect information for this study. Subsequently, more information regarding the descriptive statistics utilised to present and analyse the data through the means of Excel, Statistica and Tableau, is provided. In the Reliability and Validity section, both concepts are defined and a power analysis is discussed. Thereafter, constructs and variables are defined and the constructs and variables relevant to the study are identified. Lastly, the ethical approval received and limitations of the study, are discussed.

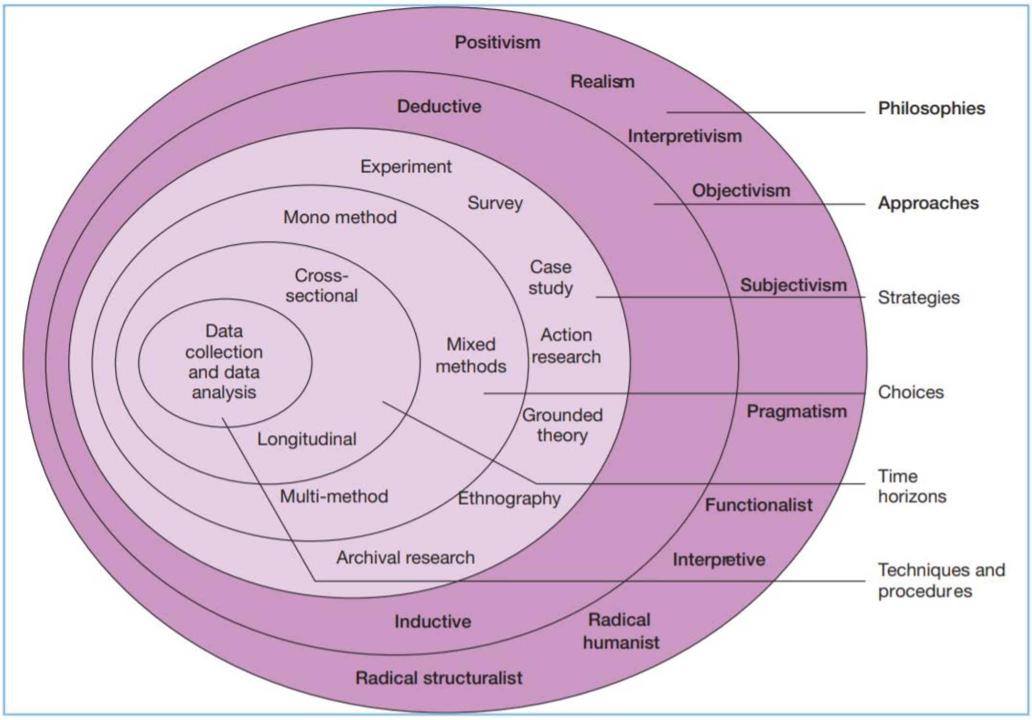


Figure 3.1: Research Onion
Source: Saunders *et al.*, 2016

3.2. Research Philosophy and Research Approach

The research philosophy used in the thesis is pragmatism, as the research questions are seen as the most important determinant of the study. The thought process that is followed when answering the research questions is that a single approach cannot answer research questions that are different from each other. Therefore, when answering research questions different approaches are used to help develop appropriate answers to each question. Pragmatism is a combination of both the positivist and interpretivist philosophies. Pragmatism uses the results collected in ways that can bring about positive consequences to the parties involved (Saunders *et al.*, 2016).

The study follows a deductive approach. Saunders *et al.*, (2016) states that deduction involves the development of a theory that is subjected to rigorous tests. The research questions were deduced from previous studies as well as the theory discussed in the literature review. The research shows how it answered the research questions (Saunders *et al.*, 2016).

3.3. Research Design

Saunders *et al.*, (2016) state that the next three layers of the "research onion", namely research strategies, research choices and time horizon, can be thought of as focusing on the process of research design. The importance of the implementation of a good research design cannot be exaggerated enough. Research design is used as a framework on which a study is built and ensures a study that is reliable and results that are accurate (Bryman, Bell, Hirschsohn, Dos Santos, Du Toit, Masenge, Van Aardt & Wagner, 2014).

Bryman *et al.*, (2014) state that a research design provides the structure that guides the use of a research method and the analysis of the subsequent data. The research design reveals to the reader how the researcher intends to express casual connections between variables, understand and explain behaviour as well as explain the meaning of the results found.

3.3.1. Research Strategies

The researcher makes use of a case study research strategy, as extensive research of a single case over an extended period of time was done (Bryman *et al.*, 2014). This strategy allowed the researcher to reach the desired objectives as well as answer the study's research questions. The case in question seeks to identify whether the different logistics processes implemented, specifically in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage, have an influence on the quality of the fruit. Saunders *et al.*, (2016) mention that the data collection techniques used in case study strategies are likely to be used in combination.

3.3.2. Research Choices

This study makes use of a mixed method research approach. Saunders *et al.*, (2016) state that a mixed method research approach makes use of both quantitative and qualitative data collection techniques. Primary as well as secondary data was collected to support the mixed methods research approach. Research tools, such as semi-structured interviews as well as questionnaires (Refer to Addendum B) were used in the study. Surveys were also sent to international blueberry experts to get a better understanding of international best practices (Refer to Addendum A). iButtons® were used during data collection to record the ambient temperature of the blueberries from harvest up until the cold store stage of the supply chain was complete.

3.3.3. Time Horizons

Saunders *et al.*, (2016) define a cross-sectional time horizon as the study of a particular phenomenon at a particular time. This study followed a cross-sectional time horizon, as the study took place at a single point in time. The research focuses on the temperature profile of blueberries and looks at various characteristics that may have an impact on the temperature profile of the initial stages of the blueberry cold chain including geographical location, logistical processes used and time of harvest.

3.4. Data Collection and Data Analysis

During data collection and data analysis it is important to note that all decisions made must be in line with the philosophies, strategies, choices and time-horizons already fixed. If not applied, the validity and reliability of the research might be in jeopardy. The researcher ensured the reliability and validity of results by researching previous studies that made use of similar data collection techniques. Previous research conducted, specifically in the cold chain of perishable produce, provided the researcher with a better understanding of what can be expected as well as what techniques are best suited for the study. This helped the researcher to consider possible deviations, while planning which data collection techniques and data analysis tools to use. As mentioned earlier, primary and secondary data was collected in support of the mixed method research approach.

3.4.1. Secondary Research

The literature review is mainly comprised of secondary data. Specific focus is placed on previous studies in order to support the current theory. Furthermore, an in-depth study was done to give credibility to the research as well as provide the researcher with sufficient information to make educated decisions. The researcher started with a broad review of literature to get an overall understanding of the topic and then focus more on specific literature to identify key elements. The information collected helped the researcher gain background knowledge on the blueberry industry, relevant terminologies and jargons used and an overall understanding of how the blueberry supply chain works. Secondary information was collected mostly from books, journals, academic articles as well as the internet.

3.4.2. Primary Research

Due to the fact that not all information could be collected from the public domain, primary research was a necessity. Primary research provides researchers with information that is accurate and up to date. The primary data collected for this study consists of both qualitative and quantitative research.

3.4.2.1. Qualitative Research

In order to gain a detailed understanding of how the blueberry supply chain works, the researcher conducted observations. In collaboration with Company X, the researcher made site visits to different blueberry farms, packhouses as well as cold stores. Semi-structured interviews were conducted with all the major role players from each section of the blueberry supply chain. The interviewees selected included a representative from the farms, packhouses, cold stores as well as the exporting company, Company X. The researcher strived to do each interview in person, however, due to unforeseen circumstances, the researcher was not able to interview everyone in person. Therefore, a questionnaire (Appendix B) was emailed to certain individuals.

3.4.2.2. Quantitative Research

In order to collect quantitative data, the study made use of temperature trials. iButtons®, a type of temperature monitoring device, were used on all the farms to record ambient temperatures experienced by blueberries throughout the beginning stages of the blueberry supply chain. The iButtons® were attached to a credit card sized holder with a long red ribbon for easy identification. This aided in the ease and speed of the retrieval of the devices. A power analysis was conducted to determine the total number of temperature monitoring devices needed for the research to collect sufficient data to make relevant deductions. The sample gave reference to the number of iButtons® required on each farm to ensure the validity of the study. In total, 54 iButtons® needed to be monitored on each farm. Temperature trials were conducted on three farms in Gauteng and three farms in the Western Cape. The three farms in the Western Cape are roughly (Farm A – 105km, Farm B – 120km and Farm C – 45km) away from Packhouse 1, which also functions as a cold store and is situated in the Robertson district. In Gauteng, Farm D is situated close to Magaliesburg, Farm E is situated in the Randfontein district and

Farm F is situated in the Modderspruit district. The blueberries were transported from each farm mentioned above to Packhouse 2, which is situated 9km from O.R. Tambo International Airport. After packaging, the pallets were transported to the cold rooms for forced cooling, which is situated at O.R. Tambo International Airport. The same tests and analysis were done on all the farms.

This section describes all the areas where iButtons® were inserted and removed. On all the farms except Farm C, iButtons® were placed in one-litre buckets during harvest and transferred to crates at the QC tables (**Figure 3.2**). The iButtons® were placed in between the blueberries as far as possible. During packing, at the Packhouse stage, the iButtons® were removed and placed in the bottom, middle and top levels of the pallets being built (**Figure 3.3**). The iButtons® were removed for a final time after forced cooling was applied at the cold room.

Figure 3.2: iButtons® in one-litre buckets during harvest and in crates at QC station
Source: Captured by the author for the purpose of the study

Figure 3.3: iButtons® placed in pallets during building of pallets at the packhouse
Source: Captured by the author for the purpose of the study

For Farm C, iButtons® were placed in lugs during harvest. These lugs were much larger than the one-litre buckets used on all the other farms. The same principles were followed on all the farms, therefore, the iButtons® were placed in between the blueberries as far as possible. The iButtons® were transferred to 4kg trays at the cold room, whereafter pallets were built (**Figure 3.4**). It is important to mention that Farm C made use of field packing, and therefore, skipped the Packhouse stage. The iButtons® were removed for a final time at the cold room after forced cooling was applied.

Figure 3.4: iButtons® in lugs during harvest, iButtons® in trays at QC tables and a completed pallet
Source: Captured by the author for the purpose of the study

3.5. Descriptive Statistics

Descriptive statistics is a way to describe and present data that helps the reader to better understand the information in front of them. McEvoy (2018) states that data is typically best described by three characteristics. The first characteristic describes how the data are centred or concentrated and is known as a measure of central tendency. The second characteristic asks how much variability exists and is known as the measure of variability, while the last characteristic looks at the overall shape of the data (McEvoy, 2018).

To better understand the information collected, the data was translated to a more descriptive form. Various options are considered when presenting the data. The data was translated using Excel, Statistica and Tableau to help the readers and stakeholders understand the basic characteristics of the data. It is important to identify which descriptive techniques were best suited for the data. The mean, median and mode were used to describe the measure of central tendency. The variance and standard deviation were used to describe the measure of variability, while clustered column, clustered column-line, etc. are some of the graphs that were used.

3.6. Reliability and Validity

Bryman *et al.*, (2014) state that reliability is concerned with the consistency or reproducibility of measures. A study is considered reliable when the same results are consistently achieved by using the same measures under the same circumstances/conditions (Middleton, 2019). The three types of reliability that determine whether a measure is consistent are test-retest, interrater, and internal consistency. Test-retest reliability refers to the consistency of measurement across time. Interrater reliability refers to the consistency of measures across observers whereas internal reliability refers to the consistency of the measurement itself (Middleton, 2019). If a study cannot ensure these three factors, the study will not be reliable (Bryman *et al.*, 2014). In order to ensure reliability, temperature monitoring devices (iButtons®) were used to measure the actual temperature rather than making use of historical data only. Identical procedures were followed on each farm to ascertain that the measure was stable over time, and therefore, ensure stability. Only one indicator, namely temperature was measured at a time. Therefore, to determine the reliability of the results the researcher assessed the consistency of the data across time, observers and parts of the tests itself (Middleton, 2019).

Bryman *et al.*, (2014) define validity as whether or not indicators that are devised to measure a concept, truly measure that concept, and if so, how accurately. The three types of evidence the validity of a measurement can be based on are: construct, content and criterion. Construct refers to the adherence of a measure to existing theory. Content is the extent to which the measurement covers all aspects of the concept being measured. Lastly, criterion is the extent to which the result of a measure corresponds to other valid measures of the same concept (Middleton, 2019). The researcher assessed the validity of the study by comparing the results to previous studies to determine how well the results correspond with existing theories that were similar. It is important to mention that a reliable study is not always valid, as the results might be reproducible, but are not necessarily correct. However, it can be said that a valid measurement is generally reliable, and therefore, if a test produces accurate results, it should be reproducible (Middleton, 2019).

To ensure validity, the assistance of a statistical expert and Professor from the Centre for Statistical Consultation (CSC) at Stellenbosch University was acquired. A power analysis was conducted to determine the total number of temperature monitoring devices needed on each farm for the research to collect sufficient data in order to reflect the concept in question. A power analysis for one-way ANOVA was done to compare six groups. The power analysis showed that an effect size of 0.25 can be detected with 90% power when samples of size 54 are used for each group in an ANOVA with significance level of 5% (**Figure 3.5**). The power is the probability of rejecting a false null hypothesis and N is the required sample size per farm.

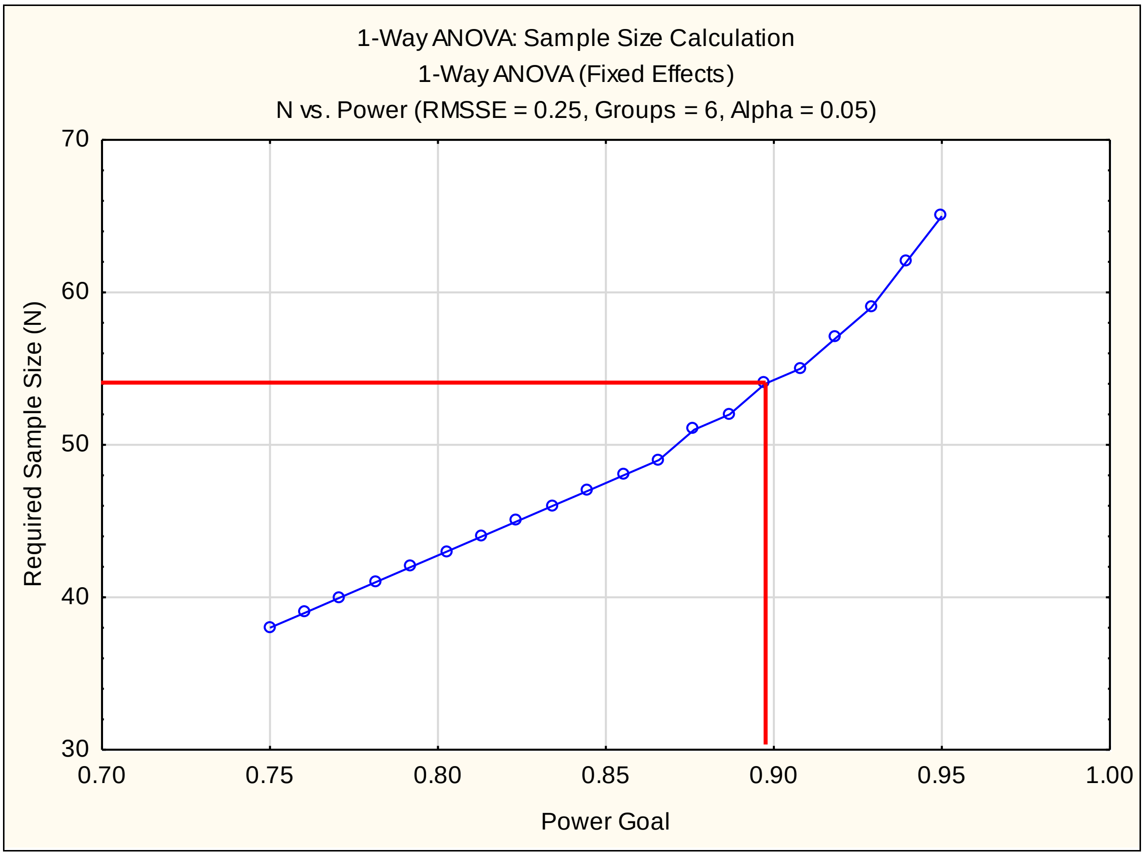


Figure 3.5: Power analysis depicting the sample size required to achieve a 0.05 level of significance
Source: Created by the author for the purpose of this study

Table 3.1 shows the number of iButtons® retrieved with usable data for each of the farm's trials conducted in the Western Cape and Gauteng. On all six farms, iButtons® were inserted during three trials, namely the Early Morning, Late Morning and Afternoon trials. Eighteen (18) iButtons® were inserted during each trial. This gave the study an element of uniformity and enabled the results to be compared.

As is the case with research, everything does not always go according to plan. Due to the fact that some of the iButtons® used were second hand, a number of them malfunctioned (**Table 3.1**). After consultation, the statistical Professor mentioned that when conducting a power analysis the analysis must be performed on the same sample size and effect size. Therefore, a power analysis was performed for six groups with a sample size of 54 and six groups with a sample size of 38. The second power analysis showed that an effect size of 0.3 can be detected with 90% power when samples of size 38 are used for each group in an ANOVA with significance level of 5%. Thus, for sample sizes ranging between 38 to 54, i.e., respectively 54, 53, 52, 46 and 38, the effect size that can be detected will be between 0.3 and 0.25, with 90% power in an ANOVA comparing six groups with such an ANOVA with 5% significance level.

Table 3.1: Number of iButtons® retrieved with usable data for each trial conducted on the farms in the Western Cape and Gauteng

Western Cape	Farm A	Farm B	Farm C	
Early Morning	18	17	18	
Late Morning	18	18	14	
Afternoon	18	17	14	
	54	52	46	
Gauteng	Farm D1	Farm D2	Farm E	Farm F
Early Morning	16	18	17	17
Late Morning	18	18	18	12
Afternoon	18	17	17	9
	52	53	52	38

Source: Compiled by the author for the purpose of the study

3.7. Constructs and Variables

Constructs are used by researchers as building blocks to help explain different components of theories. "Constructs in quantitative research" (2012) also states that constructs help the reader to better understand how and why certain phenomena behave the way they do by measuring or observing their behaviour. Wright & Lake, (n.d.) define a variable as "a characteristic or feature that varies or changes within a study." Therefore, variables are used to measure a construct (Michael, n.d.). The first and most important constructs identified for this study is temperature. Other constructs identified by the researcher are time of harvest, quality, geographical location and stage in the blueberry supply chain.

The variables identified to measure the first construct, temperature, are temperature breaks and time. Ambient temperatures are logged by temperature monitoring devices (iButtons®) that record possible temperature spikes, temperature breaks, chilling injury spikes or chilling injury breaks. Chapter two defines the above-mentioned for this study. Identified temperature breaks are measured in degrees Celsius (°C). The unit of measurement that is used to record the time, i.e., the total length that a temperature break occurred, is minutes, hours and days.

Secondly, the variables identified to measure time of harvest are time and maturity. When measuring time, a specific focus is placed on time of day. In other words, was the produce harvested during the morning hours or during the heat of the day? The unit of measurement for time is minutes, hours and days. The unit of measurement for maturity consists out of three factors, namely a sugar test (brix), a firmness test (durofel) and a colour test (colour cards developed by Company X).

The third construct identified is quality. Quality encompasses all aspects relating to the quality of the fruit. The variable identified to measure quality is quality control (QC) reports. QC reports are discussed in detail in chapter two. The units of measurement are taste, a colour test (colour cards), a firmness test (durofel), the presence of blueberry shrivelling, the potential for defects and the weight of a pallet.

The fourth construct identified is geographical location. The variables that are used to measure geographical location are temperature and seasonality. Temperature, in terms of the average temperature experienced for that region during harvest, is measured in °C. For seasonality, a specific focus is placed on the rainfall for a region that was experienced during that season and is measured in millimetres (mm).

The last construct is stages within the blueberry supply chain. Company X developed protocols that need to be followed during each stage regarding the time spent in that stage and temperature that the fruit should be at upon arrival at each stage. These protocols are discussed in Chapter 2. Therefore, the variables used to measure if the stages within the blueberry supply chain follow protocols are time and temperature. Time, in terms of the average time the blueberries spent during each stage of the blueberry supply chain. The unit of measurement that is used to record the time is minutes, hours and days. For temperature, a specific focus is placed on whether the fruit arrives and leaves each stage at the correct temperature and is measured in °C.

3.8. Ethical Considerations and Limitations of the study

This study required ethical approval as is set out in the guidelines of Stellenbosch University. Since the proposed research presented minimal risk and limited ethical issues, the ethics application process for this study was commenced within the Department of Logistics *via* the

Department Ethics Screening Committee (DESC). To proceed with the study, approval from DESC was received on 6th August 2019.

After an in-depth discussion with Company X, the company provided permission to the researcher to continue with the research and make use of industry information. Due to the competitive blueberry market and the sensitive nature of the data collected, all parties involved signed a non-disclosure agreement (NDA). The personal information of participants is protected, as pseudonyms are used for the farms, packhouses, cold stores, employees and the exporting company involved. The information gathered through interviews, conversations and observations were kept confidential on a password protected laptop.

The limitations of the study are summarized below:

- The number of new temperature devices. The temperature monitoring devices necessary to conduct this study are expensive, thus, the researcher had to make use of second-hand devices. Some devices malfunctioned and caused the researcher to lose data. Farm F was the farm most affected by this.
- Some of the interviewees were not able to provide sufficient time to work with the researcher and have an in-depth discussion due to their busy work schedules. Furthermore, some interviewees preferred completing a questionnaire rather than conducting an interview also due to a busy work schedule. Although sufficient, the researcher would have liked to probe the interviewees to gain a better understanding of some of their answers.
- The presence of the human errors. Specifically referring to the human element in the handling of temperature monitoring devices. Although the researcher was the only one to administer the handling of temperature monitor devices, handling mistakes made by the researcher need to be taken into consideration. During data collection, the researcher made a mistake by incorrectly setting the time of Farm D's iButtons®. This caused the researcher to have to run a second trial on Farm D.

3.9. Conclusion

The current study followed a deductive research approach and utilised a case study research strategy. The study consisted of both primary and secondary research, with the latter retrieved from the internet. Ethical approval from DESC was received for the study, allowing the researcher to continue with the mixed-method research approach by collecting quantitative and qualitative data. Regardless of the limitations occurring throughout the study, the researcher was able to collect reliable data, which was presented through the means of descriptive statistics.

Chapter 4: Descriptive Data Analysis

4.1. Introduction

As previously mentioned, the aim of the current study was to identify whether the different logistical processes implemented on the farms of Company X, experienced temperature breaks and whether these processes could be improved upon. Due to concerns over temperature breaks in the above-mentioned processes, Company X decided to conduct research into their blueberry cold chain. In addition, the goal was to identify whether any problems occurred in the beginning stages of the blueberry supply chain, more specifically, from the picking process up until 24 hours after the pallets were placed into the forced cooler. Therefore, the current study strived to determine whether a link existed between the logistical processes being used, possible temperature breaks and the quality of the fruit.

The fact that Company X was concerned about the presence of temperature breaks in the cold chain of blueberries, as mentioned in the study's problem statement, guided the research study. Based on these concerns, the study aimed to investigate possible causes as well as provide potential answers to unanswered questions through means of a literature review. It was important to consider the various factors that could play a role in the blueberry supply chain as Valentine & Goedhals-Gerber (2017:3) proved that geographical location of the farms, different methods of loading, off-loading and transportation on and from farms to the centralised cold storage facilities, and the trade-off between the time of harvesting and fruit quality, all had an impact on an apple supply chain. Hence, the assumption was made that the same factors could possibly have an influence on a blueberry supply chain.

4.2. South African Blueberry Supply Chain and Protocols – Company X

The first section of the blueberry cold chain begins at the farm where blueberries, in South Africa, are predominantly handpicked and placed into one-litre buckets (Cold Chain Specialist, 2019). Harvesting occurs during the morning hours or during the day depending on the weather. Harvesting is done continuously on weekly, sometimes bi-weekly intervals depending on the variety and time of season (Cold Chain Specialist, 2019). According to Eck, Gough, Hall & Spiers (1990) blueberries are picked when they reach the 100% blue stage. Cold Chain Specialist (2019) mentioned that the 100% blue stage is for domestic markets and when fresh produce is sent *via* airfreight. However, if the blueberries are sent *via* sea freight, harvesting commences at the 85-90% blue stage. Blueberries are grown in tunnels or under shaded netting. This contributes to the growth of the berries as well as protecting the berries from hale.

Pickers need to be well trained to identify which blueberries are ready to be picked as the export customers have high standards that need to be met. Pickers are required to harvest all mature fruit from a bush before continuing to the next bush. If a one-litre bucket is full, pickers tip the one-litre buckets into a crate at the QC table that is positioned in the shade, usually in or just outside the orchard, whereafter the picker will continue harvesting. At the QC table, quality control personnel examine the harvested fruit and remove undersize, green, or damaged berries.

A tractor-trailer, refer to **Figure 4.1**, is used to collect the crates in the field to be transported to the cold rooms on the farm, within one hour after harvesting. This form of transportation can contribute to the cold chain by shortening the time blueberries spend in the field after harvest, which will help to avoid an unnecessary increase in temperature. As mentioned in the harvesting section, blueberries should be left in the shade after harvest to keep the temperature of the blueberries as low as possible and to avoid excessive acceleration of respiration (Boyette, Estes, Mainland & Cline, 1993). By loading and unloading blueberries efficiently, the time harvested blueberries spend in the field can be kept to a minimum. The sooner blueberries arrive at the cold room; the sooner field temperature can be brought down by pre-cooling. Therefore, the importance of a farm having a good logistical system in place, specifically referring to the transportation from the field to the cold room cannot be emphasised enough.

Figure 4.1: Tractor-trailers
Source: Captured by the author for the purpose of this study

Equipping the trailers of a tractor-trailer with netting is another way of trying to keep the temperature of blueberries as low as possible. Supply Chain Specialist (2019) mentioned that Company X expects all tractor trailers to have netting as it provides important shade while blueberries are loaded, in transit and offloaded at the cold room. As can be seen in **Figure 4.1**, it is recommended that the offloading area at the cold room should have a roof to provide additional shading as congestion can occur during offloading. This congestion can cause blueberries to stand in the sun, causing the blueberries' temperatures to rise and have a negative impact on the cold chain. Van Hoorn (2004), states that it is important that blueberries remain still during transit. Smooth and slow rides to the cold room causes less bruising, and therefore, have a positive effect on the cold chain as less handling will be required.

When the blueberries arrive at the cold room, they are immediately pre-cooled to 6ºC (Cold Chain Specialist, 2019). A refrigerated truck is used to transport pre-cooled blueberries from the farm to the packhouse. An airlock-system is compulsory to move the pallet from the cold room into the reefer truck. Both the reefer truck and the cold room are regulated at 6ºC. The same protocol is required when delivering the pallets at the packhouse; here sorting, inspection, packaging, and palletisation take place. The packhouse is regulated at 6ºC. It should be noted that no additional transportation by reefer truck is needed after this stop for the Western Cape region, as the packhouse and cold store are situated at the same location.

Before the produce is placed on a pallet, it must be graded and sorted into packaging. In order to qualify for international markets, the blueberries must comply with certain criteria. Finished pallets are moved to a cold room until a reefer truck collects the finished pallets and transports them to the nearest cold store where forced cooling to 0ºC is applied (Fresh Food Trade SA, 2018). For the Gauteng based farms, transportation is used to transport the finished pallets from the packhouse to the cold stores where forced-air cooling is applied. It should be noted that only the Gauteng based farms make use of this kind of transport as the packhouse and the cold store are situated at different locations. This transportation is provided by refrigerated truck to help maintain the low temperatures of the pallets. While pallets are being loaded or offloaded, it is important that pallets should not stand in the sun and that the processes are smooth and efficient.

As mentioned in section 2.9, Company X has various farmers that grow blueberries for the company. To ensure that the ideal cold chain is maintained to deliver the best possible quality of blueberry, Company X developed protocols that need to be followed by every farmer growing for Company X. **Table 4.1** is a summary of these protocols. The protocols give insight into the expectations of Company X with regard to the temperatures maintained and time in minutes spent during each stage of the blueberry supply chain. This research attempts to assist Company X determine whether these protocols were met, and if not, to provide Company X with possible reasons why the protocols were not followed.

Table 4.1: South African blueberry supply chain and protocols

Time specific protocols during each stage of the blueberry cold chain			
Stage	**Time per stage in Minutes**	**Total Time in Minutes**	**Temperature**
Harvest	T0-T30	T0-T30	Try to harvest blueberries during low temperatures of the day 10-30˚C. Trays and buckets should not be left in the sun.
Quality check (QC) and transport to cold room	T0-T30	T30-T60	QC and transport blueberries in shaded areas to keep temperatures down between 10-30˚C. Transport berries in trailers with shading.
Receive crates and built pallets in cold room	T10-T20	T60-T80	Receive crates in shaded area between 10-30˚C. Build pallets with the crates in cold room at 6˚C.
Pre-cooling	T180-T300	T80-T380	Use forced cooling to bring field heat of blueberries down to 6˚C. Make sure pulp of blueberries and centre of pallet is at 6˚C before stopping forced cooling. Place force cooled berries in cold room of 6˚C.
Transport to packhouse	Depends on farms distance from packhouse.	-	Make use of an airlock when loading and unloading

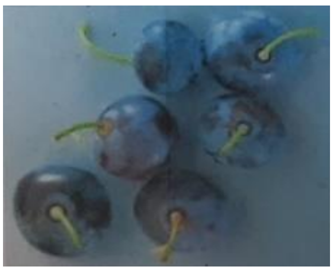
			blueberries. Reefer trucks should be pre-cooled to 6˚C.
Arrive at packhouse	T0-T1440	T380-T1440	Blueberries should arrive at 6˚C. Packhouse temperature is set at 6˚C.
Receive, inspect, and place in cold room	T0-T20	T1440-T1480	Temperature of pallets received should be measured, weighed, and inspected. Thereafter be placed in a cold room at 6˚C.
Packaging	T0-T20	T1480-T1500	Packaging room should be set at 6˚C. Place pallets in holding cold room at 6˚C.
Transport to forced cooler	T0-T20	T1500-T1520	Make use of an airlock when loading and unloading blueberries. Reefer trucks should be pre-cooled to 6˚C.
Forced Cooling	T0-T600	T1520-T2120	Use forced cooling to bring pallet temperature of blueberries down to 0˚C. Make sure pulp of blueberries and centre of pallet is at 0˚C before stopping forced cooling. Place force cooled berries in cold room 0˚C.

Source: Created by the author for the purpose of this study

In addition, as mentioned in section 2.12, temperature fluctuations could have a significant impact on the quality of fruit, and therefore, should ideally be removed, however, if not possible kept to a minimum. Section 2.13 mentions that quality control is of vital importance to ensure that exported fruit is of high quality and the correct size and colour. This research attempts to assist Company X with quality assurance by identifying a link between the temperature breaks observed during the beginning stages of the blueberry cold chain and the quality control reports received at the end. However, before quality assurance can be performed, a better understanding of quality control reports needs to be established. **Table 4.2** summarises the quality factors and their allowed tolerance level that play a role in the local and export market, as set out by Company X.

Table 4.2: Standards and requirements for blueberries to be packed for export and local market as set out by Company X

Quality Parameters	Description / Specification	Photo	Allowed tolerance level	
			Local Retailers	UK Retailers
1. Eating Quality & Brix	*Berries should be firm, juicy, and sweet with aromatic balanced flavour.* **Export = Minimum 10°B** **Local = Minimum 9°B**		0%	0%
2. Size	*Fruit should be packed uniform in size.* **<u>Export & Local retailers:</u>** **Min 12mm diameter** **<u>Municipal market & freezing:</u>** **Min 9mm diameter**		10%	5%
3. Colour	*Berries must be evenly deep blue in colour all over the fruit, no green, red or purple colour is allowed at the stem end of fruit.* **ONLY berries in the top row of the picture are allowed. Berry in the top right-hand corner must be within allowed tolerance levels.**		10% 0%	5% 0%
	Bloom is the natural whitish surface appearance of the fruit and highly sought after. This should cover the whole			

4. Bloom	*fruit and care must be taken when handling fruit as it can easily rub off.* **Export = only full bloom allowed** **Local = average bloom is allowed, where bloom is not prominent and/or has been partially rubbed off.**		-	-
5. Firmness	*Fruit should be firm to the touch. Fruit that is soft and bladdery is not allowed. Firmness is measured using the Agrosta as a Durofell index.* **Export = Minimum 50** **Local = Minimum 40**		-	-
6. Shrivelling	*Fruit should be firm and fresh. Shrivelling is caused by fruit age and moisture loss.* **Not allowed**		5%	2%
7. Flower Ends	*There should be no dried flowers left that stick to the flower end of the fruit. These are carriers of spores of disease forming bacteria and fungi.* **Not allowed**		0%	0%
8. Stems	*There should be no stems attached to the fruit after harvesting. This may indicate that fruit were harvested immature.* **Not allowed**		0%	0%

9. Malformation	*The cause of malformation is subject to speculation.* **Not allowed**		10%	5%
10. Injuries	*Care should be taken when handling fruit to avoid damage such as nail marks and mechanical damage during harvesting and handling. Injuries caused by birds and insects should be graded out.* **Not allowed**		0%	0%
11. Skin Cracks / Splitting	*There are many factors that contribute to blueberries' skins cracking or splitting. Most frequently it is rain induced, where plants receive a large amount of rainfall just before harvest.* **Not allowed**		3%	0%
12. Picking Tear Marks (Stem pull)	*Care should be taken when harvesting to avoid fruit skin tearing. Normally when tearing occurs the fruit is not ready for harvest.* **Not allowed**		3%	0%
13. Blemishes / Sunburn	*Blemishes can be caused by wind, hail, insects, or sunburn.* **Export = Not allowed.** **Local = the total area of blemish may not exceed 10% of fruit surface, provided that no internal damage has occurred.**		5%	5%

14. Bruising / Internal Damage / Cold Damage	*Damages in the form of dark irregular blotches underneath the skin surface.* **Not allowed**		5%	5%
15. Insects / Pests / Spiderwebs	*There are many insects or pests that may be present on blueberries. Care must be taken to remove fruit with insect infestation such as spider webs.* **Not allowed**		0%	0%
16. Collapsed / Bladdery / Bleeding berries	*Any fruit with a wet, oozing, or bladdery appearance should not be packed.* **Not allowed**		0%	0%
17. Rots & Moulds	*Some fungal deposits could be present on the skin of the fruit such as grey mould (Botrytis & Alternaria), fluffy white mould (Storage mould) and orange masses of fungal spores (anthracnose).* **Not allowed**	  	0%	0%
18. Combined defects	*The total combination of deviations should not exceed the allowed tolerance levels, provided that such deviations are individually within specific limits.*		10%	5%

**Fruit must be free from any external signs of spray residues and foreign objects such as soil and bird droppings.*

Source: Compiled by the author from interactions with representatives from Company X, 2020

In addition, Company X and retailers make use of a colour grading system when giving a pallet an overall score from the samples selected. **Table 4.3** shows the four colours, namely green, amber, red and black (reject), used to describe the state of a pallet, as well as a description of what each colour represents. When grading a pallet according to the colour grading system, all quality parameters (**Table 4.2**) should have been considered. Furthermore, the three main deciding factors of whether fruit is to be exported or sold locally are taste, durofel and bloom. It is important to mention that each blueberry variety is different in terms of taste, durofel, brix and bloom. Therefore, different varieties cannot be scored on the principles of a single variety. **Table 4.4** displays the average taste score requirements, as well as the minimum and premium brix for each of the blueberry varieties in order for the product to be eligible for exportation. Furthermore, a durofel test, commonly known as a firmness test, is performed to determine the mode of transportation to the exporting country. If the fruit does not meet a specific durofel level, it will not be eligible for exportation, as it would be too soft and bladdery upon arrival in the export country. **Table 4.5** shows the durofel levels required for each blueberry variety to be transported by sea, air, sold locally or finally frozen/rejected.

Table 4.3: The four colour categories used to grade the final QC outcome of a pallet

GREEN	Product is suitable for sea freight provided the rest of the quality parameters are suitable for sea freight.
AMBER	Product is only suitable for air freight and domestic retailers, provided the rest of the quality parameters are suitable for air freight.
RED	Product is only suitable for domestic retail, provided the rest of the quality parameters are suitable for domestic retail.
REJECT	Fruit will be rejected and may be sent for freezing or dumped, depending on the severity of other defects.

Source: Compiled by the author from interactions with representatives from Company X, 2020

Table 4.4: Varietal specifications for taste and brix as prescribed by Company X

Variety Name	Average Taste Score	Minimum Brix	Premium Brix
EB12-19	8	12	16
EB8-46	8	12	15
EB8-42	8	12	14
EB9-12	7	12	14

Source: Compiled by the author from interactions with representatives from Company X, 2020

Table 4.5: Durofel requirements for each blueberry variety to determine the fruit quality and mode of transport

Variety Name	Green (Suitable for sea freight)	Amber (Airfreight and Local only)	Red (Local only)	Reject (Freeze only)
EB8-46	>60	55-59	45-54	<45
EB9-12	>60	55-59	45-54	<45
EB8-42	>55	50-54	45-49	<45
EB9-2	>55	50-54	45-49	<45
EB12-19	>55	50-54	45-49	<45
EB8-50	>60	50-59	45-49	<45

GREEN	• Each parameter is within specification and total defects are below 5%. • Minimal sorting will be required to meet customer specifications.
AMBER	• One or more of the set parameters are out of specification and/or total defects found are between 5% and 10%. • Sorting will be required to meet customer specifications; depending on the severity of / or the defect(s) found, the pallet may be downgraded to be sold locally.
RED	• Total defects found are above 10% per sample. • A second QC is to be conducted before finalizing the QC report. • Sorting will be required to meet customer specifications; depending on the severity of / or the defect(s) found, the pallet may be downgraded to be sold locally.
REJECT	• Fruit will be rejected and may be sent for freezing or dumped, depending on the severity of other defects.

Source: Compiled by the author from interactions with representatives from Company X, 2020

Figure 4.2 is an example of a typical quality control report used to grade a pallet. Firstly, the function of a QC report is to provide information regarding the blueberries in terms of the variety, origin, date of harvest, supplier, consumer, etc. Secondly, export markets make use of QC reports to grade the pallets received. QC reports provide information to exporting companies regarding the quality and the condition of the blueberries upon arrival. Lastly, QC reports are used as a guide to determine and explain the reasons behind the price for each pallet Company X will receive from the importing company.

Date of Inspection		Arrival Date	
Packhouse		Supplier	
Product		Country of Origin	
No Cases Received		Variety	
No Pallets Tested		Vehicle Condition	
PO / Lot / Lot Item		Vehicle Temp	
KG Inspected		Product Temp	
Harvest Date		Range	
Traceability Codes		Temp Recorder No	
Freight Type		AirWayBill Number	
		Supplier Reference	
		Inspected By	

OVERALL SCORE ON ARRIVAL	Amber

Quality Assessment			
Contamination		**Pest Damage**	
Size		**Pest Presence**	
Shape		**Taste**	Sweet
Colour	4.72	**Brix**	10.96
Scarring		**Temperature**	3.27
Shrivel		**Packaging**	
Firmness		**Labels**	
Bleeding		**Weight**	3,530.70
Disease	2.69	**Inner Packaging**	Bulk
Spray Deposits		**Outer Packaging**	Orange box
Stems Attached			

ADDITIONAL COMMENTS	

Brix Readings	10.20 11.00 10.40 10.50 11.00 12.00 10.20 11.00 10.40 10.50 10.80 10.40 10.00 10.50 11.00 12.20 13.00 12.00 11.00 11.00	AVG: 10.96
Weights	3522 3548 3524 3522 3536 3536 3547 3525 3500 3547	
Estimated Yield	**90%-96%**	

Figure 4.2: Example of a QC report used to grade pallets
Source: Company X, 2020

4.3. Interviews

As discussed in section 3.4, primary research was conducted through the collection of qualitative and quantitative data. To gain a better understanding of how the blueberry supply chain works the researcher conducted observations as well as semi-structured interviews, which is a subset of the quantitative data that was collected. This section discusses the information collected from the semi-structured interviews conducted with the key role players from the farms, packhouses, cold stores as well as the export company, Company X.

Question 1: What areas in the beginning stages of the blueberry cold chain do you think are problem areas and require improvement?

The interviewees identified the following problem areas in the beginning stages of the blueberry cold chain that require improvement. Firstly, from the field to the cold room, more focus should be placed on reducing the overall temperature of the fruit. In addition, emphasis should be placed on the use of gazebos to provide shade as well as on a fast turnaround time regarding the loading and offloading of crates between the field and the cold room. Compared to the farms in Gauteng, the farms in the Western Cape are not as advanced in terms of their cold rooms. Although the farms in the Western Cape have improved their cold room facilities, they are striving for continuous improvement, with specific reference to their packing and holding rooms. Furthermore, during pre-cooling, the forced cooling machines take too long to remove field heat and lower the fruits' temperature to the protocol temperature of 6ºC. This slow pre-cooling process causes a bottleneck effect in the cold room, or even worse, delays the harvesting of mature fruit. The main concerns at the packhouse lie with the fruit received from the farms that do not comply with protocols as prescribed by Company X. Fruit were often received that contained condensation on the surface or were not pre-cooled to the protocol temperature of 6ºC. An additional area of concern is linked to the cooling units that leak water onto the fruit.

Question 2: Which areas in the beginning stages of the blueberry cold chain are susceptible to temperature breaks occurring?

The loading and offloading of pallets at the farms and the packhouses are considered the stages that are the most susceptible to temperature breaks occurring. The lack of an air-lock system and loading bay were the main reasons given for causing possible temperature breaks. It was also mentioned that certain trucks have an insufficient width, resulting in the last two pallets being loaded without an air-lock. Another reason suggested why possible temperature breaks could occur was pallets being removed from cold rooms and placed outside before loading commenced. In addition, the packhouse does not have an offloading bay that accommodates small trucks or trailers. Thus, if the standard reefer truck is not used, the fruit are susceptible to temperature breaks. Lastly, it was the opinion of a farm manager interviewed that the blueberries could be susceptible to temperature breaks while in the packing room when the sorting and packing of pallets take place.

Question 3: What measures have been put in place to reduce the occurrence of temperature fluctuations on the farm/ in the packhouse/cold store?

The managers employed at the farms in the Western Cape and Gauteng have implemented several measures to reduce the occurrence of temperature fluctuations. One interviewee mentioned that the turnaround time from the field to the cold room has been shortened by approximately 30 minutes on his respective farm. Whereas another interviewee mentioned that focusing on the development of efficient farming practises, ensures that pallets arrive at the cold room within 45 minutes. Examples of such a practise include the use of runners during harvest, to reduce the walking time for pickers. Another common response from the interviewees was the implementation of shaded netting on trailers, which provide 80% shade as well as allow enough airflow. The implementation of gazebos at QC stations was also mentioned. Furthermore, Packhouse 1 has installed alarms in each cold room to notify employees when temperatures become too hot.

Question 4: What strategies/plans are currently being undertaken to improve efficiency in the beginning stages of the blueberry cold chain?

Each farm manager assesses the turnaround times, at the end of the season, with continuous improvement as the end goal. In addition, more focus will be placed on providing shaded areas for the fruit that has been harvested. An interviewee mentioned that they are currently engaging with an external company to provide an identification bracelet to each packer and checker. This will allow the farm manager to track the number of one-litre buckets each picker harvests and QC personnel examine. The identification bracelet will provide the farm manager with better transparency and will ensure a better final product. Furthermore, an interviewee mentioned that a loading bay at the cold room is currently being planned. One packhouse implemented a third packing line to improve efficiency. In addition, this packhouse is planning to identify more temperature sensitive areas in the packhouse. The third packing room as well as the loading and offloading of pallets have been identified as problem areas thus far. Furthermore, the other packhouse mentioned that the development of a brand-new packhouse is in process. The new packhouse will not be as crowded as the current packhouse and will be equipped with loading and offloading bays as well as working air-lock systems. This will ensure a more temperature sensitive loading and offloading process as well as more efficient cooling and packing systems.

Question 5: What actions are taken to reduce congestion at the orchard/farm/packhouse/cold store?

An interviewee mentioned that one-litre buckets are brought to the pickers at the beginning of each day. This avoids congestion and time wasted with regards to pickers standing in a queue to receive one-litre buckets, before the start of harvest. Furthermore, a farm manager mentioned that the drivers of tractor-trailers are instructed to drop off empty trailers at the QC station, when collecting the trailers filled with blueberry-packed crates. Before implementing this strategy, the farmers had to acquire enough tractors and trailers for this practise to operate effectively. It is the opinion of a packhouse manager that a packhouse facility should be big enough to easily move around in, even when the packhouse is at full capacity. To reduce congestion at the holding, packing, and cold rooms, the entrance and exit should not be at the same location, and preferably should not share a door. Furthermore, it was mentioned that direct field packing removes the packing process from the packhouse and that drop-off schedules eliminate congestion.

Question 6: What steps are taken should there be a backlog in the schedule (i.e., not sufficient blueberries to finish a pallet, power outage, etc.)?

A farm manager mentioned that a back-up generator is in place, in the event of a power outage. In addition, if a full pallet cannot be completed due to insufficient blueberries, the half pallet is still sent to the packhouse. Another interviewee mentioned that a first in first out (FIFO) protocol is followed in the case of a power outage, as they do not have a back-up generator. In addition, a back-up truck would be arranged to transport the blueberries to the packhouse, as the policy of Company X states that the blueberries cannot remain at the farm for longer than 48 hours. One of the common problems at the one packhouse is that they often fall behind the packing schedule. To counteract this problem, direct field packing is used.

Question 7: What logistical processes (i.e., harvesting, transportation, packaging) need improvement to ensure a higher quality blueberry on arrival in the destination country?

The loading and offloading facilities are considered the main areas where more improvements can be made throughout the beginning stages of the blueberry supply chain. It was mentioned that various facilities are not equipped with loading bays or air-lock systems, hence loading and offloading sometimes take place at ambient temperature. In addition, an interviewee mentioned that the one packhouse is too small, and therefore, struggles to manage during the peak of the season. It is the opinion of the same interviewee that a bigger packhouse would solve this problem. Furthermore, it was also mentioned that packaging can always improve, to allow better airflow, reduce vibration and preserve the quality of the fruit.

Question 8: On average, how long does it take to complete each process in the beginning stages of the blueberry supply chain with regards to the movement of blueberries (i.e., how long does it take for the fruit to be moved from the field to the cold room? How long does it take for the pallets to be loaded onto a truck and how long does it take for the pallets to be offloaded at the cold store)? Is this on par with industry standards?

When discussing the movement of blueberries in the blueberry supply chain, one of the interviewees mentioned that blueberries spend approximately 45 minutes in the field. This includes the picking and QC of the fruit. The loading at the field, transportation and offloading at the cold room takes about 15 minutes. The interviewee did not mention what the normal timeline is of their cold room process. The loading of pre-cooled pallets, for transportation to the packhouse, takes approximately 30 minutes. Another interviewee did not share details regarding the time spent to complete each process in the beginning stages of their blueberry supply chain. However, it was mentioned that the farm is newly established, therefore, the production is not enough to fill a reefer truck with 20 pallets. The farm makes use of shared transportation, to reduce costs. The goal of the farm is to keep the time from harvest to the loading of pre-cooled pallets, for transportation to the packhouse, within 24 hours. Since the farm relies on other farms to provide pallets to fill a reefer truck, the process is sometimes prolonged to 48 hours. The interviewee declined to share information regarding the beginning stages of their blueberry supply chain. However, it was mentioned that the farm and transportation to packhouse stages of their blueberry supply chain are completed within approximately 15 hours. At the packhouse, from when a pallet is offloaded until it arrives in the cold room, takes approximately 45 minutes. The packing and completion of pallets take approximately 30 minutes. Thereafter, the loading of pallets, transportation to the forced cooler and offloading of pallets, take approximately 30 minutes.

Question 9: If personnel were provided with additional training, do you think it would improve the cold chain of blueberries (i.e., farm workers, truck drivers, sorters, and

packers, etc.)? If yes, what would the training include and what areas of the beginning stages of the blueberry supply chain would this training focus on specifically?

All the interviewees agreed that additional training for personnel would improve the blueberry cold chain. They mentioned that training should be simplified and focus on specific areas. However, the main theme should be to continuously keep the temperature of blueberries within the required protocols. The specific areas of focus should include harvesting, QC stations, and the cold room. One interviewee mentioned that workers, managers and even owners do not always understand the importance of cooling or why specific protocols should be followed. It was mentioned that if the positive effect cooling has on blueberries could be translated into "monetary" worth; the invested individuals would gain a better understanding of what effect their role has on the outcome of the blueberry cold chain.

Question 10: To what extent are blueberries harvested at the optimal time of the day?

This question had a wide array of answers and interpretations. One interviewee mentioned that the time-of-day blueberries are harvested does not matter if the temperature throughout the day remains cool. When probing an interviewee about using two harvesting shifts, one in the morning and one in the afternoon to avoid the midday heat, the interviewee simply stated that it would be unrealistic. The interviewee explained that half-day work would be too difficult to manage and would, therefore, not suffice. Furthermore, the type of blueberry cultivar plays an important role in the durability of the fruit. The continuing or suspension of harvesting between 12 and 4pm on warm days, is determined by the type of blueberry cultivar being harvested. The interviewee mentioned that if temperatures exceed 34ºC, it is best to suspend harvesting. In addition, it was mentioned that blueberry cultivars such as EB8-46 and EB9-2, can only be harvested during the morning or late afternoon. The EB8-42 blueberry cultivar, on the other hand, has a better durability and can, therefore, be harvested between 12- and 4pm on warm days where temperatures are below 34ºC. However, it was mentioned that some farmers would rather harvest throughout the heat and obtain a poor-quality blueberry, than leave the blueberry on the bush to harvest the next day, and subsequently face even more problems. These problems include blemishes, shrivelling or burst blueberries.

Question 11: What impact does the geographical location have on the growth and quality of the blueberry?

The geographical location plays a pivotal role in the growth and quality of blueberries, especially when the fruit are grown in the ground instead of in bags. It is recommended that the soil have a ‘sandy type’ characteristic that would provide minimum resistance to the roots of the blueberry bush. In addition, this type of ‘loose’ soil is known to provide excellent drainage, which is very important for blueberries. The ideal soil has a pH level of between 4.5 and 5. Some farmers prefer to grow blueberries in a bag, as it is easier to change the pH level of the ground in a bag, than when the bush is planted directly in the ground. In addition, it is easier for the farmer to control the concentration of nutrients absorbed by the blueberry bush, when the bush is planted in a bag. Furthermore, blueberry farmers make use of drippers to provide water to the blueberry bushes. Clean, high-quality water was stated as a necessity by all interviewees, as drippers that provide the bushes with important nutritional factors, easily get clogged. An interviewee mentioned that blueberries should be planted at a location with high cold units, as it causes the blueberry flowers to bloom and set equally. A negative effect of a location with high cold units is that the blueberries could freeze. An interviewee mentioned that the locations of some of the farms where trials were conducted at, experience high temperatures in the summer, which could ultimately have a negative impact on the quality of blueberries.

4.4. International best practices

To gain a better understanding of the different blueberry supply chains used worldwide, a survey (refer to Appendix A) was sent to experts in the industry from leading blueberry export countries. In addition, this survey helped to indicate whether the current blueberry supply chain protocols used in South Africa are on par with international standards and if not, identified what improvements need to be made. This section discusses the different types of blueberry supply chains in the respective countries as well as highlights some international best practices.

4.4.1. South African Blueberry Supply Chain – Independent Supplier

After a discussion with an independent South African blueberry supplier, the following protocols were identified. The farmer makes use of a greenhouse system to plant and grow their blueberries. The only difference from the standard shaded netting used on most farms is that they place an emphasis on the management of temperatures within these greenhouses. This is done by installing an extra layer of shaded netting within the greenhouse to regulate the temperature by opening and closing these shaded nets depending on the radiation of the sun and temperatures of the day. Mist sprayers are installed to ensure that the temperature of blueberries does not exceed a specific temperature and lastly, fans are installed to establish the desired humidity.

It is important to note that for this specific supply chain, the greenhouse and the packhouse are about five hundred metres from each other. This is important as the farms in the above mentioned South African blueberry supply chain first need to transport the harvested blueberries to a cold room to be pre-cooled. Thereafter, the pallets get transported by reefer truck to the packhouse. In this scenario, the packhouse is situated on the farm. The protocol being followed is that tractor-trailers should transport the harvested blueberries to the packhouse from the field within 40-60 minutes. Pre-cooling is implemented at the packhouse by using forced cooling. Forced cooling is only applied for one hour as the pallet's temperature drops to the desired temperature of 5˚C within this time frame. Dummy crates are strategically placed within the pallet being forced cooled in order to improve the airflow and ensure efficient cooling. After pre-cooling, the blueberries get packed by an automated machine with the ability to sort and size the blueberries. The temperature inside the packhouse is set between 2˚C and 5˚C, never exceeding 5˚C. Packaged pallets are forced cooled for one hour or until the pallet reaches the desired temperature of 0˚C.

4.4.2. Blueberry Supply Chain and Protocols – Spain and Portugal

In Spain and Portugal, blueberries get harvested as early as sunrise. During spring and summer, temperatures get very high in the afternoon. During warm days, the protocol is that workers work continuously without taking breaks and end earlier in order to pick the fruit before the strong midday heat starts. International blueberry expert (2020) states, that in a perfect world, specifically referring to the larger, professional growers, every picking team has its own tractor-trailer dedicated to a picking team. This tractor-trailer will transport the harvested fruit to the cold room situated on the farm every 20-30 minutes. International blueberry expert (2020) mentioned that this is not always realistic and stated that a turnaround time of 60 minutes is more achievable. Furthermore, in Europe, most growers are small to medium size, and therefore, cannot justify building their own cold rooms.

Instead, small to medium sized growers rent refrigerated vehicles to cool their blueberries. After harvest, the pickers take the blueberries to small huts/sheds where the fruit is placed in punnets or trays, which have no lid on the top. These huts function as an offloading bay and provide shading for the fruit and a place for quality inspectors to do a quick visual inspection. In contrast with South Africa, if the fruit is not at the right standard, the picker must sort out the fruit before they can deposit it. From the shed, the fruit gets placed directly into the refrigerated vehicles. International blueberry expert (2020) mentioned that this practise is wrong as they are continuously putting hot fruit into the truck with fruit that has already been cooled from one hour before. This creates a lot of condensation and has a negative effect on the blueberries (International blueberry expert, 2020).

When referring to the professional growers with cold rooms situated on the farm, the following protocols are followed to ensure blueberries arrive at the cold room within one hour. The first tray that gets deposited at the shed receives a paper with the time stamped on it. When the driver comes to collect the pallets, he/she must examine the paper to identify how long it has been since the first fruit has been sitting there. The driver must then inform the person receiving the fruit at the cold room to document the time and identify if the protocol is being followed. If not, the cold room manager needs to inform the farm manager in order for him to either: tell the truck driver to drive faster; talk to the workers or assign another tractor-trailer to the picking team.

International blueberry expert (2020) stated that pallets get pre-cooled using forced cooling at the cold room, in order to remove field heat to a temperature of 12˚C. It should be noted that the cold rooms on the farms use the same cooling systems as used during forced cooling mentioned in the South African Blueberry Supply Chain and Protocols. After pre-cooling the fruit gets transported by reefer truck to the packhouse. The use of an airlock is compulsory, and fruit gets transported at 12˚C. International blueberry expert (2020) mentioned that vibration during transport has a significant impact on the quality of the fruit. This was identified after the top layers of pallets were most often damaged. This is explained by referring to an earthquake. When looking at an earthquake, the base of a building is always more steady than the top of a building. The same happens with a pallet when being transported (International blueberry expert, 2020). After an examination, it was found that the fruit on the top layers had less bloom due to excessive rubbing. Therefore, the protocol is that drivers need to equip their trucks with softer suspension and growers must repair their roads as often as possible.

Packhouses are set at 12˚C. The reason for this is that it is law that the packhouse must provide workers with protective clothing if the temperature is set below 12˚C. The following two packhouse protocols need to be followed. Firstly, only one pallet is allowed to be in the packaging area at a time, because it is a high-risk area with people moving around machinery and motors are warm. The goal of the protocol is to minimize the risk for the fruit to get warm. Secondly, the importance of the packaging and the fruit being maintained at the same temperature cannot be exaggerated enough (International blueberry expert, 2020). The farmers with the best fruit quality are those that keep their packaging in the refrigerator before packaging. Packed pallets get transported directly to the forced coolers where forced cooling is applied, and the temperature is brought down to 2˚C. The temperature of the pallets should fall from 12˚C to 2˚C within 45-60 minutes. Thereafter, the pallets get placed in a cold room to maintain the temperature at 2˚C.

The final protocol that Spain and Portugal follow includes the whole blueberry supply chain. Responsibility and documentation are one of the most important protocols in this supply chain. For example, it is the responsibility of the truck driver to use a laser thermometer to check and document the temperature of the pallets and determine whether they are correctly pre-cooled to 12˚C. In the case that sufficient cooling was not applied, the driver should refuse the pallet. The same applies to the grower and packhouse. This ensures that each section of the supply chain is kept accountable.

4.4.3. Blueberry Supple Chain and Protocols – Peru

After examining Appendix A, the Peru blueberry expert (2020), stated that Peru follow the same protocols used by Company X as the farmers need to uphold the same standards as the rest of Company X's suppliers. However, the Peru blueberry expert (2020) mentioned that only a handful of growers are at the same level in terms of development as South Africa. Peru has a lot of small to medium size growers, but for this study the Peru blueberry expert (2020) only focused on the well-established growers. These growers follow the following protocols. Blueberries need to be delivered to the cold room within 60-90 minutes from harvest. At the cold room, pre-cooling is applied by a forced cooling system for about 45-60 minutes to reduce the field heat to 5°C. After pre-cooling, the cooled pallets get stored in a cold room at 5°C for 3 to 24 hours, depending on when the reefer truck arrives to transport the pallets to the packhouse. At the packhouse, the regulated temperature is 5°C and packaging of the product takes approximately one to two hours. Thereafter, the finished pallets are transported to the forced cooler to lower the temperature to 0°C. Forced cooling is applied for one to two hours. The Peru blueberry expert (2020) mentioned that one of the major problem areas in the beginning stages of the Peru blueberry supply chain is that fruit needs to be moved from one point to another for the supply chain to be completed. This creates unnecessary fluctuations in temperatures, which can create temperature breaks and the occurrence of condensation. Small to medium growers do not have the capital to build cold rooms or a packhouse on their farms. Even well-established growers in Peru have only recently acquired cold rooms.

4.5. iButtons®

To identify if the above-mentioned factors have an influence on a blueberry supply chain and whether temperature breaks do occur, quantitative data was collected by the means of temperature trials along the beginning stages of a blueberry supply chain. As mentioned in the Data Collection and Data Analysis section of Chapter 3, a power analysis was conducted that determined that 54 iButtons® should be used on each of the six farms to collect data that can be used to make a compelling argument. Furthermore, each farm was divided into three time-trials while conducting the research, namely Early Morning, Late Morning and Afternoon. Eighteen iButtons® were used during each trial. This was done to identify if different protocols were implemented as the day progresses. Furthermore, it will help to identify whether there was a significant difference in terms of what a blueberry experiences depending on what time of day it is harvested and if it could possibly have an influence on the quality of the berry. The researcher travelled to Gauteng from 8 to 14 September 2019 to collect data from Farms D, E and F. The same tests and analysis were followed while collecting data from Farms A, B and C in the Western Cape from 30 September to 20 November 2019.

4.5.1. Western Cape

Table 4.6 indicates the number of iButtons® that provided usable data while conducting trials in the Western Cape. **Table 4.6** shows that none of the iButtons® malfunctioned during the trial conducted at Farm A. However, at Farm B two iButtons® malfunctioned, one during the Early Morning trial and one during the Afternoon trial. Farm C had eight malfunctioning iButtons® in total, with four malfunctioning during the Late Morning trial and another four in the Afternoon trial.

Table 4.6: Number of iButtons® retrieved with usable data for each trial conducted on the farms in the Western Cape

Western Cape	Farm A	Farm B	Farm C
Early Morning	18	17	18
Late Morning	18	18	14
Afternoon	18	17	14
	54	52	46

Source: Compiled by the author for the purpose of the study

The reason for these malfunctions could be because of a bad connection between the iButtons® and computer while programming the iButtons®. However, in most cases it is because of the age of some of the iButtons®. It should be mentioned that due to the expensive nature of the iButtons®, the researcher could not afford new iButtons® for each farm but did try and use the new iButtons® as often as possible as they are reusable.

4.5.2. Gauteng

Table 4.7 indicates the number of iButtons® with usable data retrieved from the trials conducted in Gauteng. It is important to mention that a technical error while programming the iButtons® for the trial of Farm D resulted in the researcher having to run another trial. The reason for the error is that the researcher mistakenly programmed the iButtons® to start recording at 07:00 pm instead of 07:00 am. Although inconvenient, the researcher was still able to use the data collected during the first trial at Farm D. The researcher, therefore, renamed Farm D's trials to Farm D1 and Farm D2 to indicate the two trials that were conducted on the same farm.

Table 4.7 shows that two iButtons® malfunctioned at Farm D1 during the Early Morning trial, while at Farm D2, one iButton® malfunctioned during the Afternoon trial. On Farm E, two iButtons® malfunctioned, one during the Early Morning trial, and one during the Afternoon trial. Farm F had 16 malfunctioning iButtons® in total, with one malfunctioning during the Early Morning trial, six malfunctioning during the Late Morning trial and another nine in the Afternoon trial.

Table 4.7: Number of iButtons® retrieved with useable data for each trial conducted on the farms in Gauteng

Gauteng	Farm D1	Farm D2	Farm E	Farm F
Early Morning	16	18	17	17
Late Morning	18	18	18	12
Afternoon	18	17	17	9
	52	53	52	38

Source: Compiled by the author for the purpose of the study

4.6. Average Time Spent Per Stage

As mentioned in the motivation section of the study, the aim of the study is to identify where (if anywhere) temperature breaks occur along the beginning stages of a blueberry supply chain. While collecting data, the researcher realised that these stages would have to be clearly identified to avoid any confusion while analysing the data. After examining the protocols set out by Company X, the researcher divided the data into six stages: 1) Harvest and Transportation, 2) Pre-Cooling, 3) Transportation to Packhouse, 4) Packhouse, 5) Transportation to Forced Cooling, and 6) Forced Cooling. This segmentation of the supply chain allows the researcher to identify whether farms comply with the protocols set out by Company X. Furthermore, it helps the researcher identify the average time a blueberry spends in each stage of the cold chain.

The Harvest and Transportation stage includes the harvesting of blueberries, the quality control in the field as well as the transportation of the blueberries to the cold room. Blueberries are transported to the cold room in crates. Once they reach the cold room, the crates are stacked onto pallets. After completion of a pallet, the pallet gets weighed, labelled, and moved into the pre-cooling room. Protocol dictates that the fruit should be in the cold room within one hour after harvest begins. However, not all farms have an extra cold room to work in while completing a pallet. Furthermore, crates arrive in batches, therefore, pallet builders had to wait for more crates to finish an incomplete pallet before pre-cooling could commence. Therefore, the protocol of Company X provides pallet builders with 20 minutes to complete a pallet before pre-cooling should be applied. In other words, although the blueberries were technically in the cold room facility as protocol dictates, the blueberries were standing in a normal room without cooling. When comparing to the protocol, this caused a problem regarding uniformity as certain farms had an extra cold room while others did not. The researcher, therefore, made the decision to define the beginning of the Pre-Cooling stage and the end of the Harvest and Transportation stage as when a finished pallet was positioned against the forced cooling machine and the machine was turned on for pre-cooling to commence. This made sense as most of the farms had the same facilities regarding pre-cooling. Therefore, the Harvest and Transportation stage should be completed within 80 minutes (1.33 hours).

As mentioned above, the Pre-Cooling stage starts when the forced cooling machine during pre-cooling is switched on. Pallet temperatures are brought down to 6ºC to get rid of field heat and then moved to a cold room to maintain these temperatures until a truck arrives to transport the pallets from the farm to the packhouse. The Transportation to Packhouse stage begins as soon as the pallets are being loaded into a reefer truck and ends as soon as the last pallet gets offloaded at the packhouse after completion of its journey.

The Packhouse stage starts as soon as the pallets are being weighed in the packhouse. From there, the pallets are moved to a cold room while waiting to be packed. The necessary inspections are done before packaging commences. After packaging, the PPECB inspects the newly packed pallets where after the pallets are placed in a cold room to maintain the protocol temperature of 6ºC before being transported to forced cooling.

The Transportation to Forced Cooling stage begins as soon as the pallets are moved out of the cold room of the packhouse. Once again, a temperature of 6ºC must be maintained while in transit. Upon arrival at the forced cooling location the same procedures regarding cold room facilities were not followed. Gauteng's forced cooling facilities did not make use of their cold rooms before pallets were placed inside forced cooling units. The Western Cape did not have to transport their pallets to another location as the forced cooling system was located at the packhouse, although the pallets still had to travel to another building.

Therefore, the researcher defined the Forced Cooling stage to start as soon as the forced cooling machine was switched on. The Forced Cooling stage ended 24 hours after the temperatures were brought down to 0ºC or if the pallets had to be shipped.

4.6.1. Western Cape

Table 4.8 shows the average time in hours an iButton® spent in each stage of the blueberry supply chain, during the Western Cape trials.

Table 4.8: Western Cape – Average time per stage

Western Cape		Stages in the Blueberry Cold Chain						
		Harvest and Transportation	Pre-Cooling	Transportation to Pack House	Pack House	Transportation to Forced Cooler	Forced Cooler	Total Time
A	Early Morning	2,58	25,67	3,00	13,42	0,42	57,67	102,75
	Late Morning	1,17	25,58	3,08	13,42	0,42	57,67	101,33
	Afternoon	1,42	22,17	3,00	13,42	0,42	57,67	98,08
	Average Time	1,72	24,47	3,03	13,42	0,42	57,67	100,72
B	Early Morning	1,83	20,92	6,08	31,83	0,42	17,67	78,75
	Late Morning	1,75	18,25	6,08	31,83	0,42	17,67	76,00
	Afternoon	2,75	14,50	6,00	31,83	0,42	17,67	73,17
	Average Time	2,11	17,89	6,06	31,83	0,42	17,67	75,97
C	Early Morning	2,67	3,17	1,75	0,17	1,25	35,75	44,75
	Late Morning	3,08	17,92	2,08	0,17	2,58	15,67	41,50
	Afternoon	2,00	17,92	2,08	0,17	2,58	15,67	40,42
	Average Time	2,58	13,00	1,97	0,17	2,14	22,36	42,22

Source: Compiled by the author for the purpose of the study

4.6.1.1. Harvest and Transportation

When referring to **Table 4.8**, Farm A was the most efficient of all the farms in the Western Cape, as can be seen with the lowest average time of 1.72 hours spent during this stage. If not for the long Early Morning trial of 2.58 hours, Farm A could have been close to the expected protocol average of 80 minutes (1.33 hours). The reason for this is that Farm A managed to complete the Late Morning trial within the protocol time while the Afternoon trial came very close. Farm B, although not as efficient as Farm A, had the Afternoon trial that caused the farm's overall average to be just above two hours with an average time of 2.11 hours spent during this stage. Lastly, Farm C had the longest average time of 2.58 hours spent during this stage. However, it should be mentioned that due to light rainfall, harvest was suspended for 30 minutes. The reason for this is that during the Late Morning trial of harvest the pickers had to wait for the rain to stop as well as the fruit to dry before picking could continue. Farm C also made use of field packing, which takes longer to fill as they use three-litre lugs compared to the one-litre buckets used by the rest of the farms in the Western Cape and Gauteng (**Figure 4.3**).

Figure 4.3: Three-litre lug on Farm C compared to one-litre buckets used on the rest of the farms
Source: Captured by the author for the purpose of the study

4.6.1.2. Pre-Cooling

The Early Morning trial of Farm C only experienced 3.17 hours of pre-cooling as a reefer truck arrived to collect pallets to be transported to the packhouse as can be seen in **Table 4.8**. The pallets from the Late Morning and Afternoon trials of Farm C as well as all the trials of Farm A and Farm B were only transported to the packhouse the following day as can be seen by the long hours in the Pre-Cooling stage. Farm A experienced the longest Pre-Cooling stage with a maximum of 25.67 hours and an average time of 24.47 hours spent during this stage. Interestingly, Farm B shows how the time spent in the pre-cooler decreases as the berries are only received later in the day for the Afternoon trial compared to the Late Morning trial and then the Early Morning trial.

4.6.1.3. Transportation to Packhouse

This stage is dependent on the distance the farm is from the packhouse as well as how much traffic there is on the road. However, in the Western Cape, some farmers share transportation to cut costs, as up and coming farms cannot always fill a reefer truck with 21 pallets on their own. This can cause the travel time from farm to packhouse to be longer than expected as can be seen in **Table 4.8** with Farm B spending an average time of 6.06 hours during transit. Farm A spent an average time of 3.03 hours while Farm C spent an average time of 1.97 hours during this stage.

4.6.1.4. Packhouse

Table 4.8 shows the three vastly different average times spent during the Packhouse stage of the blueberry supply chain for the three farms in the Western Cape. Farm A spent an average of 13.42 hours, while Farm B had the longest average time of 31.83 hours. Farm C spent an average time of just 10.2 minutes in the Packhouse stage. It is important to remember that Farm C made use of field packing, which does not require the blueberries to be sorted and packaged as is needed with blueberries from Farms A and B.

4.6.1.5. Transportation to Forced Cooling

Farms A and B spent an average time of 25.2 minutes in the Transportation to Forced Cooling stage as can be seen in **Table 4.8**. Pallets of packaged blueberries get inspected while in the Packhouse stage, while field packed blueberries as in the case with Farm C, get inspected during the Transportation to Forced Cooling stage. This can be seen from the much longer average time of 2.14 hours for Farm C.

4.6.1.6. Forced Cooling

Table 4.8 shows that Farm A spent an average of 57.67 hours in the Forced Cooling stage, more than double the average time spent by Farms B and C in the same stage. The availability of containers or transportation could be a possible reason for this big difference in time spent during the forced cooling stage. Farm B spent an average of 17.67 hours while Farm C averaged 22.36 hours during the same stage. The Early Morning trial of Farm C spent 35.75 hours while the Late Morning and Afternoon trials spent half the time with an average time of 15.67 hours.

4.6.2. Gauteng

Table 4.9 shows the average time in hours an iButton® spent in each stage of the blueberry supply chain during the Gauteng trials.

Table 4.9: Gauteng – Average time per stage

Gauteng		Stages in the Blueberry Supply Chain						
		Harvest and Transportation	Pre-Cooling	Transportation to Pack House	Pack House	Transportation to Forced Cooler	Forced Cooler	Total Time
D1	Early Morning	2,35	25,30	2,00	33,75	15,00	40,92	119,32
	Late Morning	1,08	25,30	2,00	33,75	15,00	40,83	117,96
	Afternoon	1,25	21,55	2,00	33,75	15,00	19,33	92,88
	Average Time	1,56	24,05	2,00	33,75	15,00	33,69	110,05
D2	Early Morning	1,25	23,92	2,75	#	#	#	27,92
	Late Morning	1,17	22,92	2,75	#	#	#	26,83
	Afternoon	1,00	20,08	2,75	#	#	#	23,83
	Average Time	1,14	22,31	2,75	#	#	#	26,19
E	Early Morning	9,75	12,75	3,33	7,08	15,00	31,25	79,17
	Late Morning	5,17	12,75	3,33	7,08	15,00	31,25	74,58
	Afternoon	3,75	12,75	3,33	7,08	15,00	31,25	73,17
	Average Time	6,22	12,75	3,33	7,08	15,00	31,25	75,64
F	Early Morning	1,33	21,75	2,83	15,92	9,42	38,58	89,83
	Late Morning	3,50	18,08	2,83	15,92	9,42	38,58	88,33
	Afternoon	1,33	16,33	2,83	15,92	9,42	38,58	84,42
	Average Time	2,06	18,72	2,83	15,92	9,42	38,58	87,53

Source: Compiled by the author for the purpose of the study

4.6.2.1. Harvest and Transportation

Table 4.9 shows that Farm D was the most efficient farm regarding their harvest and transportation protocols as Farm D1 had an average time of 1.56 hours spent during the Harvest and Transportation stage. The Early Morning trial for Farm D1 lasted an average of 2.35 hours causing the overall average of Farm D1 to rise above the protocol time. Both the Late Morning and Afternoon trials of Farm D1 were completed within the protocol time. However, during the re-run of trials conducted on Farm D (referred to as Farm D2), all three trials conducted during the Harvest and Transportation stage were completed within the protocol time, averaging a time of 1.14 hours. Farm E spent the longest time during this stage of the blueberry cold chain averaging 6.22 hours. All three trials for Farm E recorded longer average times than any of the other farms in the study. The longest average time was measured during the Early Morning trial with an average time of 9.75 hours. The Late Morning trial of Farm F recorded an average time of 3.50 hours. Both the Early Morning and Afternoon trials for Farm F lasted an average time of 1.33 hours, therefore, complying with the protocols as set out by Company X.

4.6.2.2. Pre-Cooling

Farms D1 and D2 spent the longest total average times during the Pre-Cooling stage with average times of 24.05 hours and 22.31 hours, respectively, as can be seen in **Table 4.9**. Farm E spent the least amount of time in this stage averaging a total time of 12.75 hours, while Farm F spent an average total time of 18.72 hours in the same stage. For Farm F, the Early Morning trial had the longest average time of 21.75 hours while the Afternoon trial had the shortest average time of 16.33 hours.

4.6.2.3. Transportation to Packhouse

As in the Western Cape, the average time spent in this stage is determined by the distance the farm is from the packhouse as well as the volume of traffic on the road. Furthermore, congestion at the packhouse can delay this stage further. Farm D1 had the shortest average time of two hours while Farm E had the longest average time of 3.33 hours. The average time was 2.75 hours for Farm D2 and 2.83 hours for Farm F.

4.6.2.4. Packhouse

Table 4.9 shows that Farm D spent the longest time in the Packhouse stage with an average time of 33.75 hours. Farm F spent an average time of 15.92 hours while Farm E spent the shortest average time of 7.08 hours. No data was recorded for the Packhouse stage of Farm D2.

4.6.2.5. Transportation to Forced Cooling

Farms D1 and E both spent an average time of 15 hours in the Transportation to Forced Cooler stage as can be seen in **Table 4.9**. Farm F spent an average time of 9.42 hours in the same stage. As mentioned above, the Forced Cooling stage only starts as soon as the forced cooling machine is switched on. No data was recorded for Farm D2 during this stage.

4.6.2.6. Forced Cooling

Table 4.9 shows that Farm F had the longest average time of 38.58 hours for the Forced Cooling stage. However, the Early Morning and Late Morning trials for Farm D1 recorded the longest times for the stage, namely 40.92 hours. The Afternoon trial for Farm D1 recorded a time of 19.33 hours, while Farm E had an average time of 31.25 hours for this stage. No data was recorded for the Forced Cooling stage of Farm D2.

4.7. Temperature Spikes and Temperature Breaks

In the Temperature Spikes and Temperature Breaks section of Chapter 2, the perpetual temperature profile defined by Freiboth, Goedhals-Gerber, Van Dyk & Dodd (2013) as "an uninterrupted series of refrigerated production, storage and distribution activities, which maintain a desired low temperature range" was mentioned. The Problem Statement section of this study refers to a study done by Haasbroek (2013), which states that a decrease in fruit quality results mainly from ineffective export cold chains. This section strives to determine if temperature spikes, temperature breaks, chilling injury spikes, and chilling injury breaks occurred during the beginning stages of the blueberry cold chain. Furthermore, it attempts to show how many and where these temperature spikes and temperature breaks occurred. As mentioned in section 2.12 a temperature break in the blueberry industry is defined as "any rise in temperature of 2°C above the product-appropriate set point, for longer than 30 minutes." Furthermore, when the temperature falls below -1.5°C for longer than 30 minutes, it can be seen as chilling injury. Lastly, when the temperature rises above the established 2°C or falls below the -1.5°C barrier, but does not last longer than 30 minutes, it is defined as a temperature spike and not a temperature break.

Table 4.10 shows that a total of 638 temperature spikes, 242 temperature breaks, 345 chilling injury spikes and 27 chilling injury breaks occurred during the trials conducted for Company X. Gauteng experienced 378 temperature spikes and 194 temperature breaks, which was more than the 260 temperature spikes and 48 temperature breaks that the Western Cape experienced. In contrast, the Western Cape experienced more chilling injuries spikes and chilling injury breaks. The Western Cape experienced 345 chilling injury spikes and 25 chilling injury breaks while Gauteng experienced no chilling injury spikes and only two chilling injury breaks.

Table 4.10: Temperature Spikes and Temperature Breaks Recorded

Province	Western Cape	Gauteng	Total
Temperature Spikes	260	378	638
Temperature Breaks	48	194	242
Chilling Injury Spikes	345	0	345
Chilling Injury Breaks	25	2	27

Source: Compiled by the author for the purpose of the study

4.7.1. Western Cape

To fully understand these fluctuations in temperature, it is important to identify on what farm these fluctuations occurred as well as in which stage of the blueberry cold chain they occurred. To get an in-depth understanding of the fluctuations, the researcher examines each farm individually to show during what time trial and stage these fluctuations occurred on the respective farms in the Western Cape.

Table 4.11 shows the number of fluctuations that occurred on each farm during the trials conducted in the Western Cape. Farm B experienced the most temperature spikes and temperature breaks, accounting for 162 temperature spikes and 37 temperature breaks. Farm A experienced 50 temperature spikes and four temperature breaks while Farm C experienced 48 temperature spikes and seven temperature breaks. Farm A experienced the most chilling injury spikes, accounting for 320 of the 345 chilling injury spikes in total. Farm C only experienced 25 chilling injury spikes while Farm B experienced none. Lastly, Farm C experienced the most chilling injury breaks with a total of 21 while Farm A experienced four chilling injury breaks. Farm B had no chilling injury breaks.

Table 4.11: Temperature Spikes and Temperature Breaks Recorded on Each Farm in the Western Cape

Western Cape	Farm A	Farm B	Farm C	Total
Temperature Spikes	50	162	48	260
Temperature Breaks	4	37	7	48
Chilling Injury Spikes	320	0	25	345
Chilling Injury Breaks	4	0	21	25

Source: Compiled by the author for the purpose of the study

Table 4.12 shows the number of fluctuations that occurred during each stage of the blueberry supply chain for the three trials in the Western Cape. The Transportation to Forced Cooling stage was the only stage to experience no fluctuation in temperature. The Forced Cooling stage had the most temperature spikes with a total of 204 followed by the Packhouse stage with 27 temperature spikes. The Harvest and Transportation stage had 22 temperature spikes with the

Pre-Cooling stage and Transportation to Packhouse stage experiencing two and five temperature spikes, respectively. Temperature Breaks were the most common during the Harvest and Transportation stage with 37 temperature breaks. Forced cooling experienced seven temperature breaks while the Transportation to Packhouse experienced four temperature breaks. Out of the 345 chilling injury spikes recorded, 328 occurred during the Forced Cooling stage while the other 17 occurred during the Packhouse stage. Most of the chilling injury breaks also occurred during the Forced Cooling stage, accounting for 23 out of the 25 chilling injury breaks. The Packhouse stage experienced two chilling injury breaks.

Table 4.12: Temperature Spikes and Temperature Breaks Recorded in Each Stage in the Western Cape

Western Cape	Temperature Spikes	Temperature Breaks	Chilling Injury Spikes	Chilling Injury Breaks
Harvest and Transportation	22	37	0	0
Pre-Cooling	2	0	0	0
Transportatoin to Pack House	5	4	0	0
Pack House	27	0	17	2
Transportation to Forced Cooling	0	0	0	0
Forced Cooling	204	7	328	23
	260	48	345	25

Source: Compiled by the author for the purpose of the study

4.7.1.1. Farm A

Table 4.13 shows the number of temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that occurred during each stage for the three trials conducted on Farm A. The Harvest and Transportation stage of Farm A experienced 15 temperature spikes in total with the longest spike lasting 15 minutes. A maximum temperature of 41ºC was recorded during the Late Morning trial that accounted for eight temperature spikes. The Afternoon trial experienced six temperature spikes while the Early Morning trial experienced one temperature spike. Five temperature spikes and four temperature breaks were recorded during the Late Morning trial of the Transportation to Packhouse stage. The longest temperature break lasted 50 minutes and reached a temperature of 11.8ºC. Two temperature spikes were recorded in both the Early Morning and Late Morning trials for the Packhouse stage with the longest spike lasting five minutes and reaching a temperature of 9.2ºC. The Packhouse stage experienced a total of 17 chilling injury spikes and two chilling injury breaks. The longest chilling injury break was recorded during the Early Morning trial, which lasted 45 minutes and reached a minimum temperature of -2.2 ºC. The Early Morning trial recorded twelve chilling injury spikes and two chilling injury breaks while the Late Morning and Afternoon trials recorded two and three chilling injury spikes, respectively. Lastly, the Forced Cooling stage experienced a total of 26 temperature spikes with the longest temperature spike lasting five minutes. The

Early Morning trial recorded ten temperature spikes reaching a temperature of 2.9ºC. The Late Morning trial recorded seven temperature spikes while the Afternoon trial recorded nine temperature spikes, reaching temperatures of 2.8ºC and 2.5ºC, respectively. A total of 303 chilling injury spikes were recorded during the Forced Cooling stage: 161 during the Early Morning trial, 60 during the Late Morning trial, and 82 during the Afternoon trial. Two chilling injury breaks were recorded, both occurring during the Early Morning trial with the longest one lasting 215 minutes (3.58 hours) and reaching a minimum temperature of -3.3ºC.

Table 4.13: Temperature Spikes and Temperature Breaks Recorded in each Stage of Farm A

		Farm A			
Stages		Early Morning	Late Morning	Afternoon	Total
Harvest &Transportation to Pre-Cooler (PT<30°C)	Temperature Spikes	1	8	6	15
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	5	15	15	x
	Max Temp in °C	30,2	41,0	37,4	x
Pre-Cooling (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Transportation to Pack House (PT = 6°C)	Temperature Spikes	-	5	-	5
	Temperature Breaks	-	4	-	4
	Longest duration in minutes	-	50	-	x
	Max Temp in °C	-	11,8	-	x
Pack House (PT = 6°C)	Temperature Spikes	2	2	-	4
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	5	5	-	x
	Max Temp in °C	9,2	8,7	-	x
	Chilling Injury Spike	12	2	3	17
	Chilling Injury Break	2	-	-	2
	Longest duration in minutes	45	5	5	x
	Min Temp in °C	-2,2	-1,7	-1,8	x
Transportation to Forced Cooler (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Forced Cooling (PT = 0°C)	Temperature Spikes	10	7	9	26
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	5	5	5	x
	Max Temp in °C	2,9	2,8	2,5	x
	Chilling Injury Spike	161	60	82	303
	Chilling Injury Break	2	-	-	2
	Longest duration in minutes	215	25	25	x
	Min Temp in °C	-3,3	-2,5	-2,4	x

Source: Compiled by the author for the purpose of the study

4.7.1.2. Farm B

The temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that were recorded during each stage for the three trials conducted on Farm B are shown in **Table 4.14**. The Harvest and Transportation stage recorded seven temperature spikes during the Early Morning trial. A total of 37 temperature breaks were recorded during this stage with 18 recorded during the Late Morning trial, 17 recorded during the Afternoon trial and two recorded during the Early Morning trial. The longest temperature break during the Harvest and Transportation stage lasted 135 minutes (2.25 hours) during the Afternoon trial. The longest temperature break during the Late Morning and Early Morning trials lasted 110 minutes (1.83 hours) and 65 minutes, respectively. The Early Morning trial recorded a temperature of 35.6ºC, while the Afternoon trial recorded a temperature of 49.5ºC. The Late Morning trial recorded the highest temperature of 51.1ºC during this stage. The Packhouse stage recorded a total of 23 temperature spikes with the longest lasting 25 minutes during the Late Morning trial. The Early Morning trial recorded four temperature spikes, the Late Morning trial recorded ten temperature spikes and the Afternoon trial recorded nine temperature spikes. The Early Morning trial reached the highest temperature of 9.4ºC during this stage. Lastly, the Forced Cooling stage recorded a total of 132 temperature spikes with 65 occurring in the Early Morning trial, 38 occurring in the Late Morning trial, and 29 occurring in the Afternoon trial for this stage. The Afternoon trial had the longest temperature spike lasting 15 minutes while the temperature spikes in the Early Morning trial and the Late Morning trial both lasted ten minutes. The Early Morning trial reached the highest temperature of 5.1ºC while the Late Morning trial reached a temperature of 4.2ºC and the Afternoon trial reached a temperature of 3.3ºC.

Table 4.14: Temperature Spikes and Temperature Breaks Recorded in each Stage of Farm B

		Farm B			
Stages		Early Morning	Late Morning	Afternoon	Total
Harvest &Transportation to Pre-Cooler (PT<30°C)	Temperature Spikes	7	-	-	7
	Temperature Breaks	2	18	17	37
	Longest duration in minutes	65	110	135	x
	Max Temp in °C	35,6	51,1	49,5	x
Pre-Cooling (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Transportation to Pack House (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Pack House (PT = 6°C)	Temperature Spikes	4	10	9	23
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	15	25	10	x
	Max Temp in °C	9,4	9,2	9,0	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Transportation to Forced Cooler (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Forced Cooling (PT = 0°C)	Temperature Spikes	65	38	29	132
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	10	10	15	x
	Max Temp in °C	5,1	4,2	3,3	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x

Source: Compiled by the author for the purpose of the study

4.7.1.3. Farm C

Table 4.15 shows the number of temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that occurred during each stage for the three trials conducted on Farm C. The Pre-Cooling stage recorded two temperature spikes during the Late Morning trial, with the longest lasting 15 minutes and reaching a maximum temperature of 9.5ºC. Forced cooling recorded a total of 46 temperature spikes with 32 occurring during the Early Morning trial, nine occurring during the Late Morning trial and five occurring during the Afternoon trial. Seven temperature breaks were recorded during the Early Morning trial with the longest lasting 385 minutes (6.42 hours) and reaching a maximum temperature of 8.8ºC. Both the Late Morning and Afternoon trials' temperature spikes lasted a maximum of 20 minutes. During the Afternoon trial, a maximum temperature of 15ºC was recorded and during the Late Morning trial a maximum of 13.9ºC was noted. The Forced Cooling stage recorded a total of 25 chilling injury spikes, with eight noted during the Early Morning trial, seven during the Late Morning trial and ten during the Afternoon trial. A total of 21 chilling injury breaks were also recorded during this stage with three occurring during the Early Morning trial, five occurring during the Late Morning trial and 13 occurring during the Afternoon trial. The Afternoon trial recorded the longest chilling injury break of 160 minutes (2.67 hours) while the chilling injury breaks from the Early Morning trial and the Late Morning trial both lasted 75 minutes. Lastly, the minimum temperature reached during the chilling injury breaks of the Early Morning trial was -2ºC, while a minimum of -2.3ºC was reached during the Late Morning trial and a minimum of -3ºC during the Afternoon trial.

Table 4.15: Temperature Spikes and Temperature Breaks Recorded in each Stage of Farm C

		Farm C			
Stages		Early Morning	Late Morning	Afternoon	Total
Harvest &Transportation to Pre-Cooler (PT<30°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Pre-Cooling (PT = 6°C)	Temperature Spikes	-	2	-	2
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	15	-	x
	Max Temp in °C	-	9,5	-	x
Transportation to Pack House (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Pack House (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Transportation to Forced Cooler (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Forced Cooling (PT = 0°C)	Temperature Spikes	32	9	5	46
	Temperature Breaks	7	-	-	7
	Longest duration in minutes	385	20	20	x
	Max Temp in °C	8,8	13,9	15	x
	Chilling Injury Spike	8	7	10	25
	Chilling Injury Break	3	5	13	21
	Longest duration in minutes	75	75	160	x
	Min Temp in °C	-2,0	-2,3	-3,0	x

Source: Compiled by the author for the purpose of the study

4.7.2. Gauteng

In contrast to the Western Cape, temperature spikes and temperature breaks were more evenly spread between all the trials done in Gauteng. To get a better understanding of which farm the fluctuations occurred on, and more specifically during what stage the fluctuations occurred, **Tables 4.16** and **4.17** are discussed. Finally, to get an in-depth understanding of the fluctuations each farm is examined individually to show during what stage and time-trials these fluctuations occurred on the respective farms in Gauteng.

The number of fluctuations that occurred on each farm during the trials conducted in Gauteng are represented by **Table 4.16**. On Farm D1, 126 temperature spikes and 45 temperature breaks were recorded. Farm D1 was the only farm where chilling injury breaks were recorded with a total of two. On Farm D2, 44 temperature spikes and 17 temperature breaks were recorded. A total of 130 temperature spikes and 73 temperature breaks were recorded on Farm E, which was the highest number for all the trials conducted in Gauteng. On Farm F, 78 temperature spikes and 59 temperature breaks were recorded. No chilling injury spikes were recorded on any farm.

Table 4.16: Temperature Spikes and Temperature Breaks Recorded in Gauteng per Farm

Gauteng	Farm D1	Farm D2	Farm E	Farm F	Total
Temperature Spikes	126	44	130	78	378
Temperature Breaks	45	17	73	59	194
Chilling Injury Spikes	0	0	0	0	0
Chilling Injury Breaks	2	0	0	0	2

Source: Compiled by the author for the purpose of the study

Table 4.17 shows the number of fluctuations that occurred during each stage of the blueberry supply chain for the trials conducted in Gauteng. Not a single stage recorded a chilling injury spike while the Forced Cooling stage was the only stage to record chilling injury breaks, with a total of two. The Harvest and Transportation stage recorded 25 temperature spikes and 55 temperature breaks while no temperature spikes and 11 temperature breaks were recorded during the Pre-Cooling stage. No temperature spikes and temperature breaks were recorded during the Transportation to Packhouse stage while 96 temperature spikes and 91 temperature breaks were recorded during the Packhouse stage. Forty-two (42) temperature spikes and two temperature breaks were recorded during the Transportation to Forced Cooling stage while the Forced Cooling stage recorded the most temperature spikes with a total of 215 while also recording 35 temperature breaks.

Table 4.17: Temperature Spikes and Temperature Breaks Recorded in Gauteng per stage

Gauteng	Temperature Spikes	Temperature Breaks	Chilling Injury Spikes	Chilling Injury Breaks
Harvest and Transportation	25	55	0	0
Pre-Cooling	0	11	0	0
Transportatoin to Pack House	0	0	0	0
Pack House	96	91	0	0
Transportation to Forced Cooling	42	2	0	0
Forced Cooling	215	35	0	2
	378	194	0	2

Source: Compiled by the author for the purpose of the study

4.7.2.1. Farm D1

Table 4.18 shows the number of temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that occurred during each stage for the three trials conducted on Farm D1. As mentioned before, due to an error made by the researcher no data was recorded for the Harvest and Transportation stage of Farm D1. A total of 29 temperature spikes and 23 temperature breaks were recorded during the Packhouse stage. During the Early Morning trial, eleven temperature spikes and five temperature breaks were recorded, while three temperature spikes and 15 temperature breaks were recorded during the Late Morning trial, and 15 temperature spikes and three temperature breaks were recorded during the Afternoon trial. The Early Morning trial had the longest temperature break for the three time-trials with a recorded time of 80 minutes while the longest temperature breaks during both the Late Morning and Afternoon trials lasted 50 minutes. A maximum temperature of 17.8ºC was recorded during the Early Morning trial and a maximum temperature of 17.5ºC during the Late Morning trial. The highest temperature of the Packhouse stage, namely 18.2ºC, was recorded during the Afternoon trial. Four temperature spikes were recorded for all three time-trials during the Transportation to Forced Cooling stage. The longest temperature spike lasted 25 minutes for both the Early Morning and Late Morning trials while the longest temperature spike of 15 minutes was recorded during the Afternoon trial. A maximum temperature of 9.2ºC was recorded during the Early Morning trial and a maximum temperature of 8.9ºC was recorded during the Afternoon trial. The highest temperature during the Transportation to Forced Cooling stage, namely 12.7ºC, was recorded during the Late Morning trial. The Forced Cooling stage recorded a total of 85 temperature spikes and 22 temperature breaks. Seven temperature spikes and eight temperature breaks were recorded during the Early Morning trial, 46 temperature spikes and five temperature breaks during the Late Morning trial and 32 temperature spikes and nine temperature breaks during the Afternoon trial. The longest temperature breaks lasted 1000 minutes (16.67 hours) for both the Early Morning and Afternoon trials, while the longest temperature break lasted 75 minutes during the Late Morning trial. The highest temperature during the Forced Cooling stage, namely 23.2ºC, was recorded during the Afternoon trial. A maximum temperature of 22.5ºC was recorded during the Early Morning trial, and a maximum temperature of 13ºC was recorded during the Late Morning trial. The Forced Cooling stage recorded two chilling injury breaks during the Early Morning trial with the longest chilling injury break lasting 645 minutes (10.75 hours) and reaching a minimum temperature of -2ºC.

Table 4.18: Temperature Spikes and Temperature Breaks Recorded in each Stage of Farm D1

		Farm D1			
Stages		Early Morning	Late Morning	Afternoon	Total
Harvest &Transportation to Pre-Cooler (PT<30°C)	Temperature Spikes	x	x	x	0
	Temperature Breaks	x	x	x	0
	Longest duration in minutes	x	x	x	x
	Max Temp in °C	x	x	x	x
Pre-Cooling (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Transportation to Pack House (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Pack House (PT = 6°C)	Temperature Spikes	11	3	15	29
	Temperature Breaks	5	15	3	23
	Longest duration in minutes	80	50	50	x
	Max Temp in °C	17,8	17,5	18,2	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Transportation to Forced Cooler (PT = 6°C)	Temperature Spikes	4	4	4	12
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	25	25	15	x
	Max Temp in °C	9,2	12,7	8,9	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Forced Cooling (PT = 0°C)	Temperature Spikes	7	46	32	85
	Temperature Breaks	8	5	9	22
	Longest duration in minutes	1000	75	1000	x
	Max Temp in °C	22,5	13,0	23,2	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	2	-	-	2
	Longest duration in minutes	645	-	-	x
	Min Temp in °C	-2,0	-	-	x

Source: Compiled by the author for the purpose of the study

4.7.2.2. Farm D2

The temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that were recorded during each stage of the three time-trials regarding the trials conducted on Farm D2 are shown in **Table 4.19**. Due to an error made by the researcher, it was necessary to conduct a second trial on Farm D2 to collect data lost during the trial on Farm D1. The researcher recorded data for Farm D2 up until the iButtons® reached the Packhouse stage. Therefore, it can be seen in **Table 4.19** that no data was collected during the Transportation to Forced Cooling stage and Forced Cooling stage. During the Harvest and Transportation stage a total of 20 temperature spikes were recorded with 18 recorded during the Late Morning trial with one recorded during the Early Morning trial and one recorded during the Afternoon trial. All 16 temperature breaks were recorded during the Afternoon trial with the longest lasting 90 minutes. The longest temperature spike lasted five minutes for the Early Morning trial while the longest temperature spike of 30 minutes was recorded for the Late Morning trial. A maximum temperature of 30.4ºC was recorded for the Early Morning trial and a maximum temperature of 37ºC for the Late Morning trial. The highest temperature for The Harvest and Transportation stage namely, 39.1ºC was recorded during the Afternoon trial. During the Pre-Cooling stage one temperature break was recorded that lasted 515 minutes (8.58 hours) and reached a maximum temperature of 13.1ºC for the Early Morning trial. The Packhouse stage recorded a total of 24 temperature spikes with eight temperature spikes occurring during the Early Morning trial, seven occurring during the Late Morning trial and nine occurring during the Afternoon trial. The longest temperature spike of ten minutes was recorded for both the Early Morning and Late Morning trials reaching a maximum temperature of 11.6ºC and 11.08ºC, respectively. The longest temperature spike of 15 minutes was recorded and reached a maximum temperature of 11.4ºC during the Afternoon trial.

Table 4.19: Temperature Spikes and Temperature Breaks Recorded in each Stage of Farm D2

		Farm D2			
Stages		Early Morning	Late Morning	Afternoon	Total
Harvest &Transportation to Pre-Cooler (PT<30°C)	Temperature Spikes	1	18	1	20
	Temperature Breaks	-	-	16	16
	Longest duration in minutes	5	30	90	x
	Max Temp in °C	30,4	37,0	39,1	x
Pre-Cooling (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	1	-	-	1
	Longest duration in minutes	515	-	-	x
	Max Temp in °C	13,1	-	-	x
Transportation to Pack House (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Pack House (PT = 6°C)	Temperature Spikes	8	7	9	24
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	10	10	15	x
	Max Temp in °C	11,6	11,8	11,4	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Transportation to Forced Cooler (PT = 6°C)	Temperature Spikes	x	x	x	0
	Temperature Breaks	x	x	x	0
	Longest duration in minutes	x	x	x	x
	Max Temp in °C	x	x	x	x
	Chilling Injury Spike	x	x	x	0
	Chilling Injury Break	x	x	x	0
	Longest duration in minutes	x	x	x	x
	Min Temp in °C	x	x	x	x
Forced Cooling (PT = 0°C)	Temperature Spikes	x	x	x	0
	Temperature Breaks	x	x	x	0
	Longest duration in minutes	x	x	x	x
	Max Temp in °C	x	x	x	x
	Chilling Injury Spike	x	x	x	0
	Chilling Injury Break	x	x	x	0
	Longest duration in minutes	x	x	x	x
	Min Temp in °C	x	x	x	x

Source: Compiled by the author for the purpose of the study

4.7.2.3. Farm E

Table 4.20 shows the number of temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that occurred during each stage for the three trials conducted on Farm E. During the Harvest and Transportation stage, a total of two temperature spikes and 36 temperature breaks were recorded. The two temperature spikes and one temperature break were recorded during the Early Morning trial, 18 temperature breaks during the Late Morning trial and 17 during the Afternoon trial. The Late Morning trial recorded the longest temperature break with a time of 215 minutes (3.58 hours), with the longest recorded temperature break for the Early Morning trial lasting 45 minutes and the Afternoon trial lasting 180 minutes (3 hours). The highest temperature for the Harvest and Transportation stage namely, 40.9ºC, was recorded for the Late Morning trial. A maximum temperature of 35.5ºC was recorded for the Afternoon trial and a maximum of 30.8ºC for the Early Morning trial. The Packhouse stage recorded a total of 26 temperature spikes and a total of 30 temperature breaks. Nine temperature spikes were recorded for the Early Morning trial, ten for the Late Morning trial and seven for the Afternoon trial. During the Packhouse stage, eight temperature breaks were recorded for the Early Morning trial, nine for the Late Morning trial and 13 for the Afternoon trial. The longest temperature break lasted for 115 minutes (1.92 hours) during the Early Morning trial, 95 minutes for the Late Morning trial and 85 minutes for the Afternoon trial. The highest temperature during the Packhouse stage recorded a maximum of 15.8ºC for the Late Morning trial, a maximum of 15ºC for the Early Morning trial and a maximum of 13.7ºC for the Afternoon trial. The Transportation to Forced Cooling stage recorded a total of 21 temperature spikes with 14 recorded for the Afternoon trial, six for the Late Morning trial and one for the Early Morning trial. Two temperature breaks in total were recorded in this stage with both recorded for the Late Morning trial. The longest lasted for 45 minutes. The longest lasting temperature spike lasted for 25 minutes during the Afternoon trial and 15 minutes during the Early Morning trial. A maximum temperature of 10.6ºC was recorded for the Late Morning and Afternoon trials, while a maximum of 8.3ºC was recorded for the Early Morning trial. Lastly, the Forced Cooling stage recorded 81 temperature spikes with one recorded for the Early Morning trial, 34 for the Late Morning trial and 46 for the Afternoon trial. A total of nine temperature breaks were recorded with one recorded for the Early Morning trial, three for the Late Morning trial and five for the Afternoon trial. The longest lasting temperature breaks recorded a time of 890 minutes (14.83 hours) for the Early Morning trial, 160 minutes (2.67 hours) for the Late Morning trial and 40 minutes for the Afternoon trial. The highest temperature reached during the Forced Cooling stage was a maximum temperature of 4.3ºC for the Afternoon trial, a maximum of 4.1ºC for the Late Morning trial and a maximum of 3.2ºC for the Early Morning trial.

Table 4.20: Temperature Spikes and Temperature Breaks Recorded in each Stage of Farm E

		Farm E			
Stages		Early Morning	Late Morning	Afternoon	Total
Harvest &Transportation to Pre-Cooler (PT<30°C)	Temperature Spikes	2	-	-	2
	Temperature Breaks	1	18	17	36
	Longest duration in minutes	45	215	180	x
	Max Temp in °C	30,8	40,9	35,6	x
Pre-Cooling (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Transportation to Pack House (PT = 6°C)	Temperature Spikes	-	-	-	0
	Temperature Breaks	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Max Temp in °C	-	-	-	x
Pack House (PT = 6°C)	Temperature Spikes	9	10	7	26
	Temperature Breaks	8	9	13	30
	Longest duration in minutes	115	95	85	x
	Max Temp in °C	15,0	15,8	13,7	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Transportation to Forced Cooler (PT = 6°C)	Temperature Spikes	1	6	14	21
	Temperature Breaks	-	2	-	2
	Longest duration in minutes	15	45	25	x
	Max Temp in °C	8,3	10,6	10,6	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x
Forced Cooling (PT = 0°C)	Temperature Spikes	1	34	46	81
	Temperature Breaks	1	3	1	5
	Longest duration in minutes	890	160	40	x
	Max Temp in °C	3,2	4,1	4,3	x
	Chilling Injury Spike	-	-	-	0
	Chilling Injury Break	-	-	-	0
	Longest duration in minutes	-	-	-	x
	Min Temp in °C	-	-	-	x

Source: Compiled by the author for the purpose of the study

4.7.2.4. Farm F

During the Gauteng trials, specifically referring to Farm F, the researcher had to adapt as packing schedules at the packhouse caused half of Farm F's blueberries to be packed and transported to the forced cooling facility while the rest were stationary in the packhouse. Although both halves of the trial followed the same process, with regards to packaging and forced cooling, the researcher had to split the data in two for the data to make sense. Therefore, an Early Morning, Early Morning 2, Late Morning, Late Morning 2 and an Afternoon, Afternoon 2 exists. **Table 4.21** shows the number of temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that occurred during each stage for the three trials conducted on Farm F. During the Harvest and Transportation stage three temperature spikes were recorded for the Late Morning 2 trial with the longest lasting a time of 15 minutes and reaching a maximum temperature of 32.2ºC. One temperature break that lasted for 40 minutes and reached a maximum temperature of 31ºC was recorded for the Late Morning trial. Two temperature breaks, with the longest lasting a time of 75 minutes and reaching a maximum temperature of 38.6ºC were recorded for the Afternoon trial. A total of ten temperature breaks were recorded during the Pre-Cooling stage with two temperature breaks recorded for the Early Morning 2 trial, four for the Late Morning trial and four for the Late Morning 2 trial. The longest temperature break recorded lasted a time of 165 minutes (2.75 hours), reaching the highest temperature of 10.6ºC for the Late Morning trial. A maximum temperature of 9.1ºC was reached with the longest temperature break lasting for 65 minutes during the Early Morning 2 trial. The longest temperature break recorded for the Late Morning 2 trial lasted for 160 minutes (2.67 hours) and reached a maximum temperature of 10.3ºC. During the Packhouse stage, a total of 17 temperature spikes were recorded with one for the Early Morning trial, five for the Early Morning 2 trial, eight for the Late Morning 2 trial and three for the Afternoon 2 trial. A total of 38 temperature breaks were recorded during the same stage with nine temperature breaks recorded for the Early Morning trial, eight for the Early Morning 2 trial, five for the Late Morning trial, seven for the Late Morning 2 trial, six for the Afternoon trial and three for the Afternoon 2 trial. The longest temperature break recorded lasted for 105 minutes (1.75 hours) during the Early Morning 2 trial while the Early Morning trial reached the highest temperature with a maximum of 12.9ºC. A total of nine temperature spikes were recorded during the Transportation to Forced Cooling stage with four temperature spikes recorded for the Early Morning and Late Morning trials and one for the Afternoon trial. The longest temperature spike lasted for 25 minutes and reached the highest temperature recorded with a maximum of 10.5ºC for the Afternoon trial. A total of 49 temperature spikes during the Forced Cooling stage were recorded with each time-trial recording at least two temperature spikes. Eighteen (18) Temperature spikes were recorded for the Late Morning trial with the longest temperature spike lasting for 20 minutes and reaching a maximum temperature of 3.2ºC. The Forced Cooling stage recorded a total of eight temperature breaks. The Late Morning trial was the only trial not to record a temperature break. The longest lasting temperature break recorded a time of 485 minutes (8.08 hours) for the Afternoon trial while the highest temperature reached recorded a maximum of 11.9ºC for the Early Morning 2 trial.

Table 4.21: Temperature Spikes and Temperature Breaks Recorded in each Stage of Farm F

		Farm F						
Stages		Early Morning	Early Morning 2	Late Morning	Late Morning 2	Afternoon	Afternoon 2	Total
Harvest &Transportation to Pre-Cooler (PT<30°C)	Temperature Spikes	-	-	-	3	-	-	3
	Temperature Breaks	-	-	1	-	2	-	3
	Longest duration in minutes	-	-	40	15	75	-	x
	Max Temp in °C	-	-	31	32,2	38,6	-	x
Pre-Cooling (PT = 6°C)	Temperature Spikes	-	-	-	-	-	-	0
	Temperature Breaks	-	2	4	4	-	-	10
	Longest duration in minutes	-	65	165	160	-	-	x
	Max Temp in °C	-	9,1	10,6	10,3	-	-	x
Transportation to Pack House (PT = 6°C)	Temperature Spikes	-	-	-	-	-	-	0
	Temperature Breaks	-	-	-	-	-	-	0
	Longest duration in minutes	-	-	-	-	-	-	x
	Max Temp in °C	-	-	-	-	-	-	x
Pack House (PT = 6°C)	Temperature Spikes	1	5	-	8	-	3	17
	Temperature Breaks	9	8	5	7	6	3	38
	Longest duration in minutes	95	105	80	80	60	55	x
	Max Temp in °C	12,9	12,4	10,7	11,7	11,3	10,9	x
	Chilling Injury Spike	-	-	-	-	-	-	0
	Chilling Injury Break	-	-	-	-	-	-	0
	Longest duration in minutes	-	-	-	-	-	-	x
	Min Temp in °C	-	-	-	-	-	-	x
Transportation to Forced Cooler (PT = 6°C)	Temperature Spikes	4	-	4	-	1	-	9
	Temperature Breaks	-	-	-	-	-	-	0
	Longest duration in minutes	20	-	20	-	25	-	x
	Max Temp in °C	8,8	-	8,6	-	10,5	-	x
	Chilling Injury Spike	-	-	-	-	-	-	0
	Chilling Injury Break	-	-	-	-	-	-	0
	Longest duration in minutes	-	-	-	-	-	-	x
	Min Temp in °C	-	-	-	-	-	-	x
Forced Cooling (PT = 0°C)	Temperature Spikes	10	2	18	7	9	3	49
	Temperature Breaks	1	1	-	1	2	3	8
	Longest duration in minutes	50	40	20	150	485	325	x
	Max Temp in °C	2,9	11,9	3,4	11,4	3,3	10,9	x
	Chilling Injury Spike	-	-	-	-	-	-	0
	Chilling Injury Break	-	-	-	-	-	-	0
	Longest duration in minutes	-	-	-	-	-	-	x
	Min Temp in °C	-	-	-	-	-	-	x

Source: Compiled by the author for the purpose of the study

4.8. Time and Stage Protocol Temperature Was Reached

4.8.1. Pre-Cooling

As mentioned in the Blueberry Cold Chain section in Chapter 2, pre-cooling is used to remove field heat to lower the pulp temperature of the blueberries below the protocol temperature of 6ºC. The protocol of Company X dictates that field heat should be removed within 380 minutes (6.33 hours) after harvest. Furthermore, it states that pre-cooling should lower the pulp temperature of the blueberries to below 6ºC within 300 minutes (5 hours) after pre-cooling commences. Given the protocols of Company X, the protocol temperature is expected to be reached during the Pre-Cooling stage of the blueberry cold chain. **Figure 4.4** and **Figure 4.6** show the shortest, longest, average, and median times in minutes it took to reach protocol temperature during each trial for the farms in the Western Cape and Gauteng. Whereas **Figure 4.5** and **Figure 4.7** indicate the stage when the protocol temperature of 6ºC was finally reached.

4.8.1.1. Western Cape

During the trials in the Western Cape, **Figure 4.4** shows that the shortest time that protocol temperature was reached was in a time of 35 minutes for the Late Morning trial on Farm C while the longest time was 3330 minutes (55.5 hours) for the Late Morning trial on Farm B. Farm B had the highest overall average and median times while the lowest overall average and median times were recorded on Farm C. It is important to mention that Farm C made use of field packing. Therefore, they used crates specifically designed to allow better airflow and this could be the reason for the lower average and median times. All three farms failed to reach the protocol temperature within the required 300 minutes in terms of their average and median times.

Figure 4.5 shows at what stage protocol temperature was reached throughout the trials for the three farms in the Western Cape. None of the farms managed to reach protocol temperature during the Pre-Cooling stage for all three trials in the Western Cape. Farm C recorded the best results with the Late Morning and Afternoon trials reaching protocol temperature during the Pre-Cooling stage. The trials conducted for Farm A showed very inconsistent temperatures as protocol temperature was reached during different stages, while Farm B was consistent in that regard, reaching protocol temperature during the Packhouse stage. However, this is far too late.

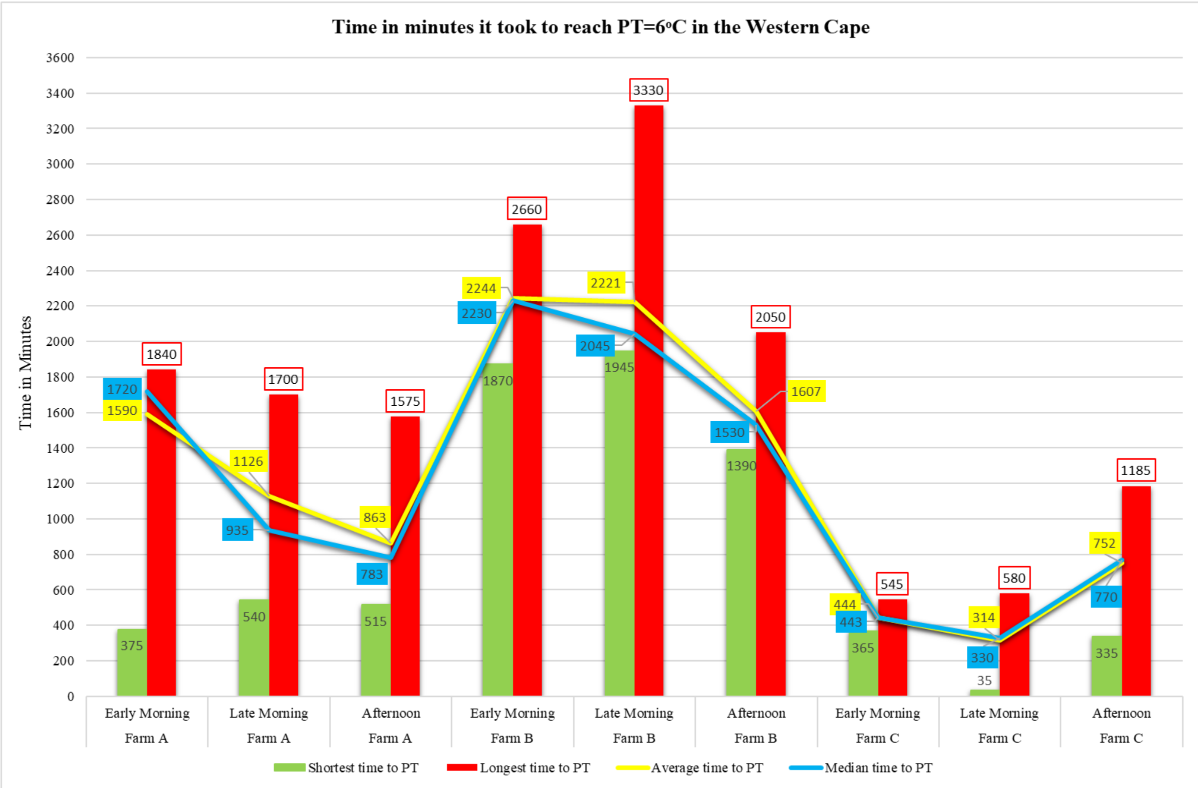


Figure 4.4: Times in minutes it took to reach PT=6ºC in the Western Cape
Source: Compiled by the author for the purpose of the study

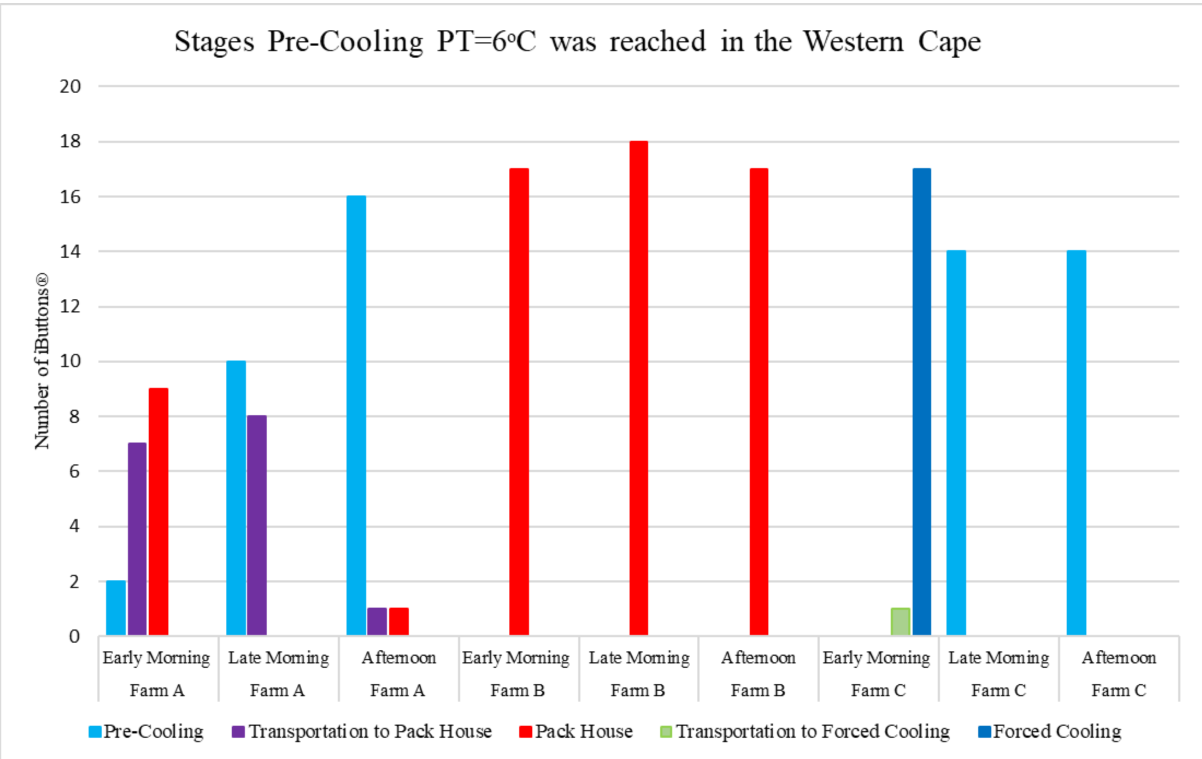


Figure 4.5: Stage where PT=6ºC was reached in the Western Cape
Source: Compiled by the author for the purpose of the study

4.8.1.1.1. Farm A

Figure 4.4 shows that the shortest and longest times to protocol temperature were recorded for the Early Morning trial with times of 375 and 1840 minutes (6.25 and 30.67 hours), respectively. Furthermore, the highest average time of 1590 minutes (26.5 hours) and median time of 1720 minutes (28.67 hours) were also recorded for the Early Morning trial. The lowest average time of 863 minutes (14.38 hours) and median time of 783 minutes (13.05 hours) were recorded for the Afternoon trial.

A lot of inconsistencies were recorded for each trial but improved as the day progressed as can be seen in **Figure 4.5**. Two iButtons® reached protocol temperature during the Pre-Cooling stage, seven during the Transportation to Packhouse stage and nine during the Packhouse stage for the Early Morning trial. Ten iButtons® reached protocol temperature during the Pre-Cooling stage and eight during the Transportation to Packhouse stage for the Late Morning trial. Sixteen (16) iButtons® reached protocol temperature during the Pre-Cooling stage, one during the Transportation to Packhouse stage and one during the Packhouse stage for the Afternoon trial.

4.8.1.1.2. Farm B

The shortest time to protocol temperature with a time of 1390 minutes (23.17 hours) was recorded for the Afternoon trial as can be seen in **Figure 4.4**. Furthermore, the lowest average time to protocol temperature with a time of 1607 minutes (26.78 hours) and the lowest median time with a time of 1530 minutes (25.5 hours) were also recorded for the Afternoon trial. The longest time to protocol temperature with a time of 3330 minutes (55.5 hours) was recorded for the Late Morning trial. The highest average and median times were recorded for the Early Morning trial with times of 2244 minutes (37.4 hours) and 2230 minutes (37.17 hours), respectively.

Figure 4.5 shows that all three trials reached protocol temperature during the Packhouse stage.

4.8.1.1.3. Farm C

Figure 4.4 shows that the shortest time to protocol temperature, with a time of 35 minutes, was recorded for the Late Morning trial. Furthermore, the lowest average and median times to protocol temperature were also recorded during the Late Morning trial with times of 314 minutes (5.23 hours) and 330 minutes (5.5 hours), respectively. The longest time to protocol temperature with a time of 1185 minutes (19.75 hours) was recorded for the Afternoon trial. The highest average time to protocol temperature, with a time of 752 minutes (12.53 hours) and median time of 770 minutes (12.83 hours), were also recorded for the Afternoon trial.

All the iButtons® reached protocol temperature during the Pre-Cooling stage for the Late Morning and Afternoon trials as can be seen in **Figure 4.5**. One iButton® reached protocol temperature during the Transportation to Forced Cooling stage and 17 iButtons® during the Forced Cooling stage for the Early Morning trial.

4.8.1.2. Gauteng

Figure 4.6 shows the shortest, longest, average, and median times recorded to reach protocol temperature for each Farm in Gauteng. The shortest time to protocol temperature, with a time of 20 minutes, was recorded for the Early Morning trial of Farm F while the longest time, with a time of 1460 minutes (24.33 hours), was recorded for the Late Morning trial of Farm D2. Farm D2 had the highest overall average and median times while the lowest overall average and median times were recorded on Farm F. The average and median times of Farms E and F managed to reach protocol temperature within the protocol time of 300 minutes (5 hours), while both trials done on Farm D failed. It is important to mention that due to the error made by the researcher as discussed in section 4.5, iButtons®, the shortest time to protocol temperature, average, and median times for all the trials on Farm D1 were based on the data that the researcher was able to collect. The above mentioned also applies to the Afternoon trial for Farm D2 as the longest time to protocol temperature, average, and median times were affected due to the error.

All the trials conducted for the farms in Gauteng except the Late Morning and Afternoon trials of Farm D2 reached protocol temperature during the Pre-Cooling stage as can be seen in **Figure 4.7**.

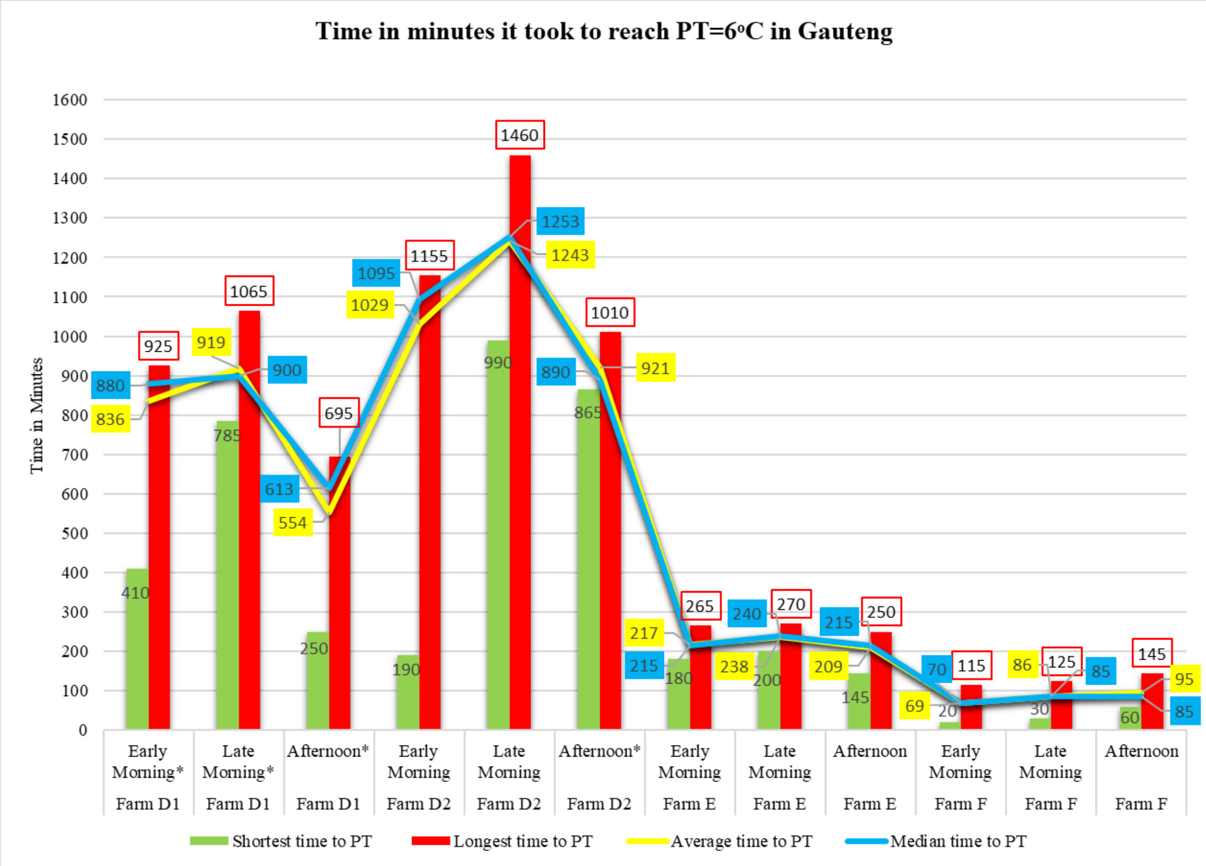


Figure 4.6: Times in minutes it took to reach PT=6°C in Gauteng
Source: Compiled by the author for the purpose of the study

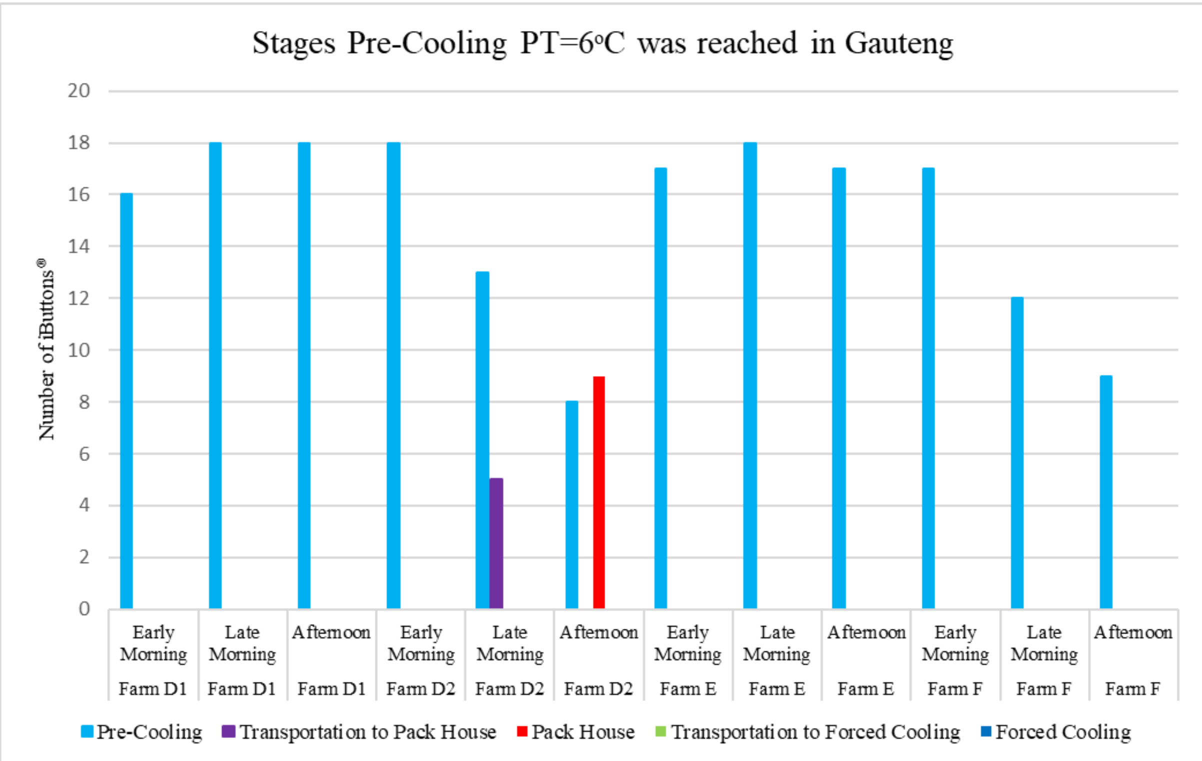


Figure 4.7: Stage where PT=6°C was reached in Gauteng
Source: Compiled by the author for the purpose of the study

4.8.1.2.1. Farm D1

Figure 4.6 shows that the shortest time to protocol temperature, with a time of 250 minutes (4.17 hours), was recorded for the Afternoon trial. Furthermore, the lowest average and median times to protocol temperature were recorded during the same trial with times of 554 minutes (9.23 hours) and 613 minutes (10.22 hours), respectively. The longest time to protocol temperature, with a time of 1065 minutes (17.75 hours), was recorded for the Late Morning trial. The highest average time to protocol temperature, with a time of 919 minutes (15.32 hours) and median time with a time of 900 minutes (15 hours), were recorded for the same trial.

Figure 4.7 shows that all three time-trials reached protocol temperature during the Pre-Cooling stage.

4.8.1.2.2. Farm D2

The shortest time to the protocol temperature, with a time of 190 minutes (3.17 hours), was recorded for the Early Morning trial as can be seen in **Figure 4.6**. The lowest average time of 921 minutes (15.35 hours) and median time of 890 minutes (14.83 hours) were recorded during the Afternoon trial. The longest time to protocol temperature, with a time of 1460 minutes (24.33 hours), and the highest average and median times, with times of 1243 minutes (20.72 hours) and 1253 minutes (20.88 hours), were recorded for the Late Morning trial.

Figure 4.7 shows that the Early Morning trial reached protocol temperature during the Pre-Cooling stage. Thirteen (13) iButtons® reached protocol temperature during the Pre-Cooling stage and seven iButtons® during the Transportation to Packhouse stage for the Late Morning trial. Eight iButtons® reached protocol temperature during the Pre-Cooling stage and nine during the Packhouse stage for the Afternoon trial.

4.8.1.2.3. Farm E

Figure 4.6 shows the shortest time to the protocol temperature, with a time of 145 minutes (2.42 hours), was recorded for the Afternoon trial. Furthermore, the lowest average and median times to protocol temperature were recorded during the same trial with times of 209 minutes (3.48 hours) and 215 minutes (3.58 hours), respectively. The longest time, with a time of 270 minutes (4.5 hours), was recorded for the Late Morning trial, with the highest average time of 238 minutes (3.97 hours) and median time of 240 minutes (4 hours) recorded for the same trial.

Figure 4.7 shows that all three trials reached protocol temperature during the Pre-Cooling stage.

4.8.1.2.4. Farm F

The shortest time to the protocol temperature, with a time of 20 minutes, was recorded for the Early Morning trial as can be seen in **Figure 4.6**. The same trial recorded the lowest average time of 69 minutes and median time of 70 minutes. The longest time to the protocol temperature, with a time of 145 minutes (2.42 hours), was recorded for the Afternoon trial. Furthermore, the highest average and median times to protocol temperature were recorded during the same trial with times of 95 minutes and 85 minutes, respectively.

Figure 4.7 shows that all three trials reached protocol temperature during the Pre-Cooling stage.

4.8.2. Forced Cooling

Forced cooling is implemented to slow down the respiration rate and preserve the blueberries while in transit to the end destination. As mentioned in the Blueberry Cold Chain section of Chapter 2, forced cooling is applied until the pulp of the blueberries reaches a protocol temperature of 0ºC. The protocol of Company X dictates that the newly packaged pallets should reach protocol temperature within 2120 minutes (35.33 hours) after harvest. As soon as Forced cooling begins protocol states that the pulp temperature should reach protocol temperature within 600 minutes (10 hours). As Forced Cooling is the last stage, it is expected that the blueberries should reach protocol temperature during this stage.

Figure 4.8 and **Figure 4.10** show the shortest, longest, average, and median times in minutes it took to reach protocol temperature during each trial for the farms in the Western Cape and Gauteng. Whereas **Figure 4.9** and **Figure 4.11** indicate the stage that the protocol temperature of 0ºC was finally reached.

4.8.2.1. Western Cape

Figure 4.8 shows the shortest, longest, average, and median times it took to reach protocol temperature for the farms in the Western Cape. The shortest time to protocol temperature with a time of zero minutes was recorded for all three trials for Farm A. The reason for this was because the iButtons® had already reached protocol temperature during one of the previous stages. Therefore, when the Forced Cooling stage started the iButtons® temperature was already 0°C. The longest time, with a time of 2225 minutes (37.08 hours) was recorded for the Early Morning trial on Farm A. Farm C had the highest overall average and median times while the lowest overall average and median times were recorded on Farm A.

The stage protocol temperature was reached throughout the trials for the three farms in the Western Cape are shown in **Figure 4.9**. All the farms, except five iButtons® from Farm A, reached the protocol temperature during the Forced Cooling stage.

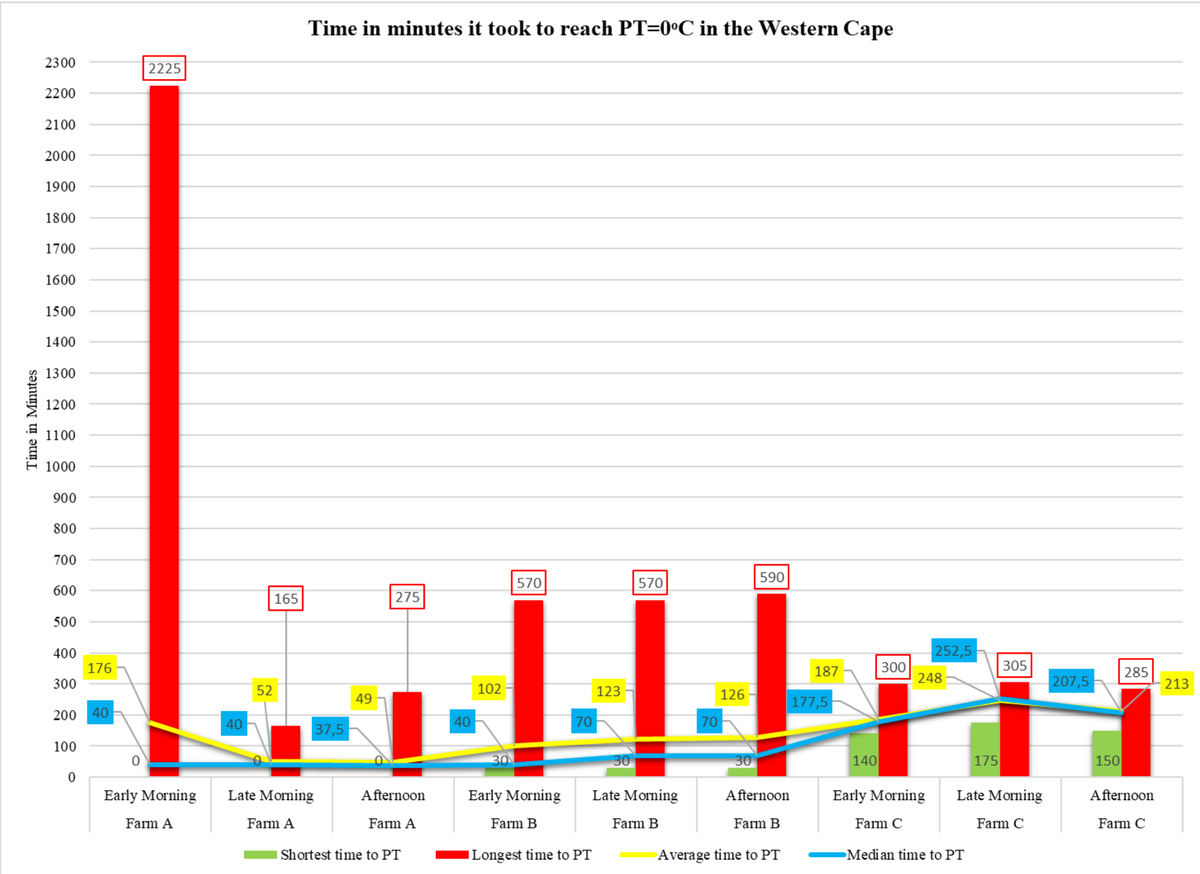


Figure 4.8: Times in minutes it took to reach PT=0°C in the Western Cape
Source: Compiled by the author for the purpose of the study

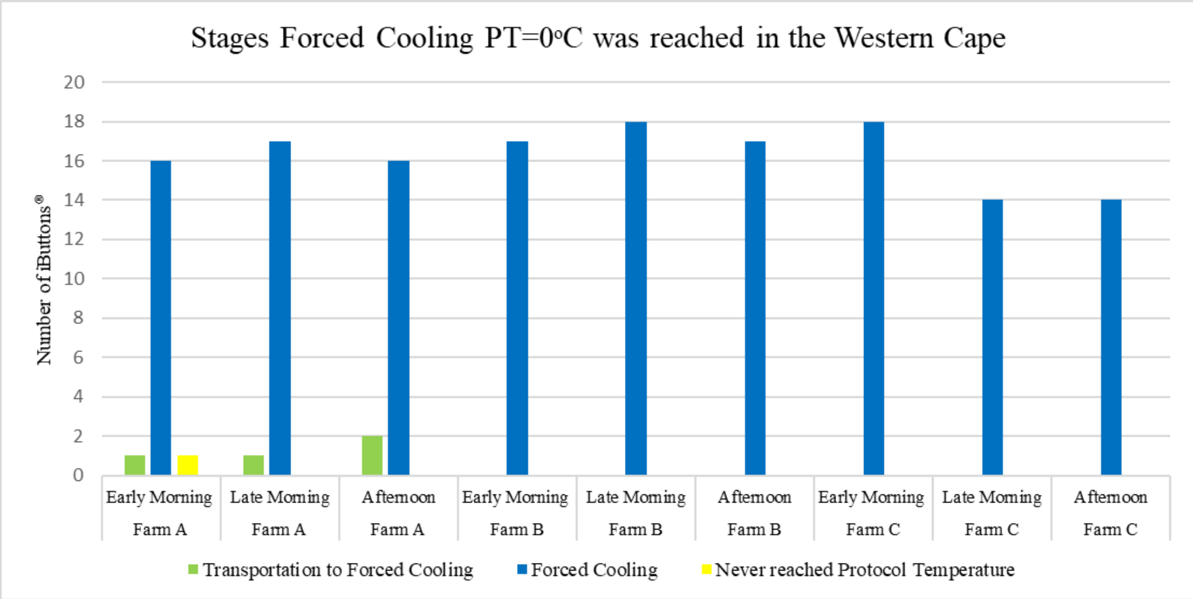


Figure 4.9: Stage where PT=0°C was reached in the Western Cape
Source: Compiled by the author for the purpose of the study

4.8.2.1.1. Farm A

Figure 4.8 shows that the shortest time to protocol temperature, with a time of zero minutes was recorded for the Early Morning, Late Morning and Afternoon trials. The longest time to protocol temperature with a time of 2225 minutes (37.08 hours) was recorded for the Early Morning trial. Furthermore, the highest average time of 176 minutes (2.93 hours) and median time of 40 minutes was also recorded for the Early Morning trial. The lowest average and median times to reach protocol temperature were recorded for the Afternoon trial with times of 49 minutes and 37.5 minutes, respectively.

Forty nine (49) iButtons® reached protocol temperature during the Forced Cooling stage while five iButtons® did not reach protocol temperature during this stage as can be seen in **Figure 4.9**. One iButton® reached protocol temperature during the Transportation to Forced Cooling stage and one iButton® never reached Protocol Temperature during the stage for the Early Morning trial. Furthermore, one iButton® reached protocol temperature during the Transportation to Forced Cooling stage for the Late Morning trial and another two iButtons® during the Transportation to Forced Cooling stage for the Afternoon trial.

4.8.2.1.2. Farm B

Figure 4.8 shows that the shortest time to protocol temperature, with a time of 30 minutes, was recorded for the Early Morning, Late Morning and Afternoon trials. Furthermore, the lowest average and median times to protocol temperature were recorded during the same trial with times of 102 minutes and 40 minutes, respectively. The longest time to protocol temperature, with a time of 590 minutes (9.83 hours), was recorded for the Afternoon trial with the same trial recording the highest average time of 126 minutes (2.1 hours) and median time of 70 minutes.

Figure 4.9 shows that all three trials reached protocol temperature during the Forced Cooling stage.

4.8.2.1.3. Farm C

The shortest time to protocol temperature, with a time of 140 minutes (2.33 hours), was recorded for the Early Morning trial as can be seen in **Figure 4.8**. The lowest average time of 187 minutes (3.12 hours) and median time of 177.5 minutes (2.96 hours) were recorded for the same trial. The longest time to reach protocol temperature, with a time of 305 minutes (5.08 hours), was recorded for the Late Morning trial. Furthermore, the highest average and median times to protocol temperature were recorded for the same trial with times of 248 minutes (4.13 hours) and 252.5 minutes (4.21 hours), respectively.

Figure 4.9 shows that all three trials reached protocol temperature during the Forced Cooling stage.

4.8.2.2. Gauteng

Figure 4.10 shows the shortest, longest, average, and median times it took to reach protocol temperature for the farms in Gauteng. The shortest time to reach protocol temperature, with a time of zero minutes, was recorded for all the trials for Farm E and the Early Morning and Afternoon trials for Farm F. The longest time to reach protocol temperature, with a time of 1875 minutes (31.25 hours), was recorded for the Early Morning trial for Farm D1. Farm D1 had the highest overall average and median times while the lowest overall average and median times were recorded on Farm F. **Figure 4.10** does not show information for Farm D2 as no data was collected after the Packhouse stage.

Figure 4.11 shows that during every trial for the farms in Gauteng protocol temperature was reached. However, for the Early Morning trial on Farms D1 and E, the Afternoon trial on Farm E, and all three trials on Farm F several iButtons® never reached Protocol Temperature. A number of iButtons® reached protocol temperature during the Transportation to Forced Cooling stage for all three trials on Farm E and, the Early Morning and Afternoons trials on Farm F.

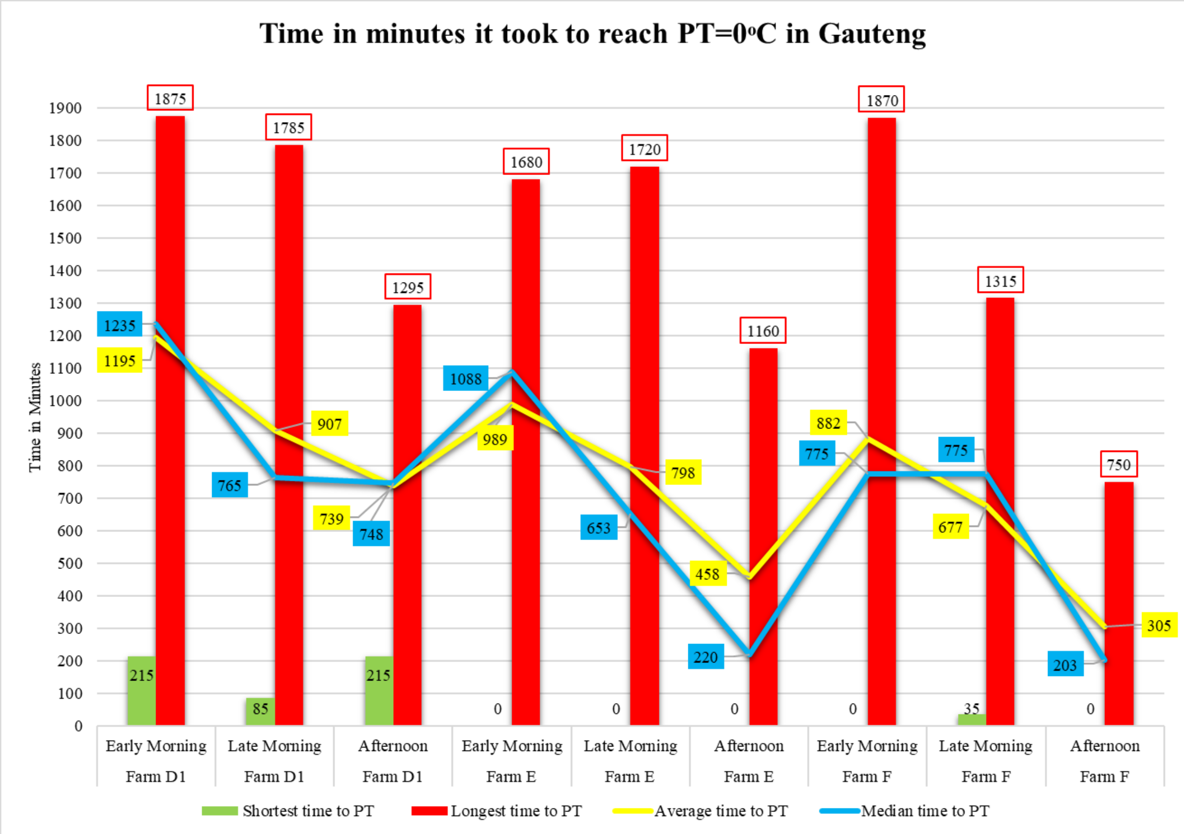


Figure 4.10: Times in minutes it took to reach PT=0°C in Gauteng
Source: Compiled by the author for the purpose of the study

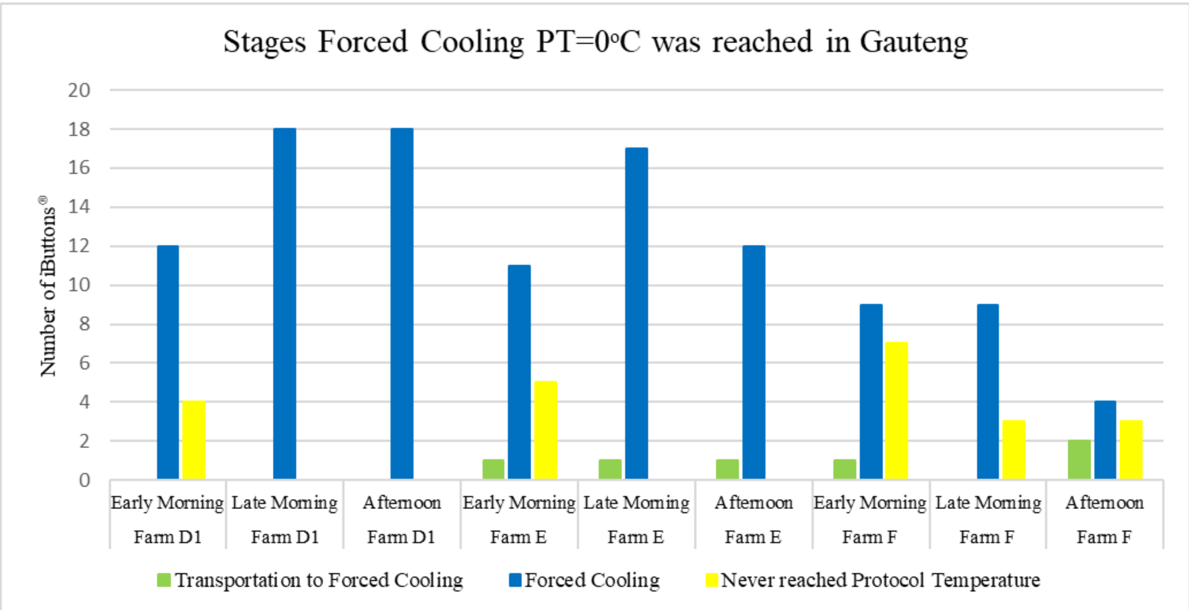


Figure 4.11: Stage where PT=0°C was reached in Gauteng
Source: Compiled by the author for the purpose of the study

4.8.2.2.1. Farm D1

Figure 4.10 shows the shortest time to protocol temperature, with a time of 85 minutes recorded for the Late Morning trial. The longest time to protocol temperature, with a time of 1875 minutes (31.25 hours), was recorded for the Early Morning trial. Furthermore, the highest average and median times to protocol temperature were recorded during the same trial with times of 1195 minutes (19.92 hours) and 1235 minutes (20.58 hours), respectively. The lowest average time of 739 minutes (12.32 hours) and median time of 748 minutes (12.47 hours) were recorded for the Afternoon trial.

Twelve (12) iButtons® reached protocol temperature during the Forced Cooling stage and four iButtons® never reached protocol temperature for the Early Morning trial as can be seen in **Figure 4.11**. All the iButtons® reached protocol temperature during the Forced Cooling stage for the Late Morning and Afternoon trials.

4.8.2.2.2. Farm E

The shortest time to protocol temperature, with a time of zero minutes, was recorded for the Early Morning, Late Morning and Afternoon trials as can be seen in **Figure 4.10**. The longest time to protocol temperature, with a time of 1720 minutes (28.67 hours), was recorded for the Late Morning trial on Farm E. The highest average time of 989 minutes (16.48 hours) and median time of 1088 minutes (18.13 hours) were recorded for the Early Morning trial while the lowest average time of 458 minutes (7.63 hours) and median time of 220 minutes (3.67 hours) were recorded for the Afternoon trial.

Figure 4.11 shows the stage protocol temperature was reached for the trial on Farm E. One iButton® reached protocol temperature during the Transportation to Forced Cooling stage, 11 iButtons® during the Forced Cooling stage and five iButtons® never reached protocol temperature for the Early Morning trial. One iButton® reached protocol temperature during the Transportation to Forced Cooling stage and 17 iButtons® during the Forced Cooling stage for the Late Morning trial. For the Afternoon trial, one iButton® reached protocol temperature during the Transportation to Forced Cooling stage and 12 iButtons® during the Forced Cooling stage.

4.8.2.2.3. Farm F

Figure 4.10 shows that the shortest time to protocol temperature, with a time of zero minutes was recorded for the Early Morning and Afternoon trials. The longest time to protocol temperature, with a time of 1870 minutes (31.17 hours), was recorded for the Early Morning trial. Furthermore, the highest average and median times were recorded for the same trial with times of 882 minutes (14.7 hours) and 775 minutes (12.92 hours), respectively. The lowest average time of 305 minutes (5.08 hours) and median time of 203 minutes (3.38 hours) were recorded during the Afternoon trial.

Figure 4.11 shows the stage protocol temperature was reached for the three trials on Farm F. One iButton® reached protocol temperature during the Transportation to Forced Cooling stage, nine iButtons® during the Forced Cooling stage and seven iButtons® never reached protocol temperature for the Early Morning trial. Nine iButtons® reached protocol temperature during the Forced Cooling stage and three never reached protocol temperature for the Late Morning trial. For the Afternoon trial, two iButtons® reached protocol temperature during the Transportation to Forced Cooling stage, four iButtons® during the Forced Cooling stage and three iButtons® never reached protocol temperature.

4.9. Logistical Processes Used and Protocols not Followed

As mentioned in section 4.2, specific protocols need to be followed to maintain the best possible quality blueberries while also maintaining the cold chain as effectively as possible. This section strives to identify areas along the initial stages of the blueberry cold chain where protocols were not followed nor applied correctly. Farms that do not comply with the protocols, as they are deemed a luxury or not a high priority, are also highlighted. Furthermore, this section strives to identify the different logistical processes and handling techniques for loading, unloading and transportation on and from farms to the centralised packhouse facility used in the Western Cape and Gauteng.

4.9.1. Western Cape

The farms in the Western Cape are quite new and less established when compared to the farms in Gauteng. All three farms in the Western Cape are developing at a rapid rate, with new blueberry bushes planted and cold rooms that are not completely up to standard. In an interview conducted with the managers of all three farms they mentioned that specific focus is being placed on cold rooms and how to improve. In addition, Farms A and B make use of one-litre buckets when harvesting while Farm C uses field packing as mentioned in the Average Time Spent per Stage section of Chapter 4.

4.9.1.1. Farm A

Farm A experienced heavy rain the week before the trials were conducted. This had a negative effect on the quality of the blueberries as the fruit bruised more easily during harvest after rain. Furthermore, it required pickers to harvest at a slower pace as pickers needed to look for healthy fruit between all the damaged fruit. On the day of the trial, it was a warm day with temperatures averaging in the high twenties. **Figure 4.12** shows that quality control had to be performed in the sun while empty crates also had no protection from the sun due to the farm's gazebos breaking the previous week, because of strong winds. A maximum temperature of 41ºC was recorded during the Harvest and Transportation stage for the Late Morning trial of Farm A, as discussed in the Temperature Spikes and Temperature Breaks section in Chapter 4. Although this is extremely hot, the reason for this could be the steel tables that absorb a lot of heat when no shade is provided by gazebos. A temperature of 37.9ºC was recorded on the steel table for the Late Morning trial as can be seen in **Figure 4.13**. In the Temperature Spikes and Temperature breaks section it is further mentioned that the Late Morning and Afternoon trials had more temperature spikes than the Early Morning trial. This confirms the importance of gazebos as the temperature started high during the morning hours but rose further as the day progressed. **Figure 4.14** shows finished crates standing in the sun instead of being placed in the tractor-trailer due to the tractor breaking down the previous week. This forced the farm to improvise and use a KIA truck as can be seen in **Figure 4.15**. Although a short-term solution, the KIA does not provide the required shading, ventilation, or stability a tractor-trailer provides. The roads between orchards are very sandy as can be seen in **Figures 4.12** and **4.14**. The road was never sprayed with water, therefore, creating a lot of dust while driving.

Figure 4.12: Empty crates standing in the sun, while quality control is performed without gazebos
Source: Captured by the author for the purpose of the study

Figure 4.13: The temperature of the steal table for the Late Morning trial
Source: Captured by the author for the purpose of the study

Figure 4.14: Finished crates standing in the sun
Source: Captured by the author for the purpose of the study

Figure 4.15: KIA truck used to replace broken tractor
Source: Captured by the author for the purpose of the study

When the loading and unloading of crates takes place at the cold room the tractor-trailers, or in this case the KIA, must park in the sun as there is no roof to provide shade as can be seen in **Figure 4.16**. This is not ideal as the crates could experience unnecessary heat while being unloaded, especially if there is congestion in the cold room. **Figure 4.17** shows how pallets were built using the crates received from the field. Protocol dictates that the pallets should be completed inside a cold room. Farm A does not have two separate refrigerated cold rooms. Only after a pallet is completed is the pallet moved into the cold room where pre-cooling can commence, as can be seen in **Figure 4.18**. The door of the packing room where pallets are built was never closed during the trial as can be seen in **Figure 4.17**. This is problematic as all the warm air from outside then flows inside as was evident when the researcher measured a temperature of 17ºC at 11:45, while the cold room, where pre-cooling was applied, measured a temperature of 8.3ºC at the same time. Therefore, protocol was not adhered to with regards to cold room temperature, as protocol dictates that the cold room should have a temperature of 6ºC. It was also determined that the cold room was set to cool to 7.5ºC. At 14:46, a temperature of 14.8ºC was recorded in the packing room while a temperature of 10ºC was recorded in the cold room. After investigation it was found that during lunch, the door of the packing room was closed while the door between the cold room and the packing room was opened. The reasoning behind this was to cool the packing room, however, this caused the cold room's temperature to rise significantly. As mentioned earlier, the farm only has two separate rooms with the one being the packing room and the other the cold room where pre-cooling is applied. The problem with this is that after pre-cooling was applied, the pallet is supposed to be moved to a separate holding room to maintain temperatures. **Figure 4.19** shows that the holding room is situated in the same cold room. The high temperature that was measured in the cold room during the day could be the reason for the inconsistencies linked to when the stage's protocol temperature was reached during pre-cooling for Farm A, as can be seen in **Figure 4.5**.

Figure 4.16: Loading and unloading of crates at the cold room
Source: Captured by the author for the purpose of the study

Figure 4.17: Building pallets in the packing room
Source: Captured by the author for the purpose of the study

Figure 4.18: Finished pallets moved to the cold room for pre-cooling to commence
Source: Captured by the author for the purpose of the study

Figure 4.19: Empty crates (left) and pre-cooled pallets (right) standing in the cold room
Source: Captured by the author for the purpose of the study

4.9.1.2. Farm B

Two days before the trials were conducted, Farm B experienced heavy rain. This had a negative impact on the quality of the blueberries since the fruit bruises more easily during harvest after rain. Furthermore, it required pickers to harvest at a slower pace as pickers needed to distinguish between healthy and damaged fruit. **Figure 4.20** shows the dirt road that leads to the various blueberry fields. If financially feasible, it is recommended that this road together with other main roads be covered with pebbles to prevent unnecessary dust while driving. An alternative suggestion could be to spray the roads with water every morning. Furthermore, protocol was not followed regarding the correct way of picking blueberries, since pickers placed their one-litre buckets on the ground, as can be seen in **Figure 4.21**. This could cause the blueberries to collect unnecessary dust and dirt when emptying the buckets at the QC table. After a discussion with the farm manager regarding this matter, it was mentioned that due to a backlog at the packhouse the farm had a shortage of crates. As a result, the farm could not provide pickers with crates to place under the one-litre buckets, preventing them from standing on the ground. In the past, a backlog at the packhouse has even caused production to stop as there were not enough crates to build pallets. During harvest, Farm B used a picking system of allocating two one-litre buckets to accomplished pickers whereas new pickers received one bucket. The reasoning behind this was to ensure that a better-quality product was received at the QC table. It is important to mention that on the day of the trial it was very hot with the temperature averaging in the high thirties. **Figure 4.22** shows how empty crates and buckets were left in the sun over lunch. Some of the buckets were not even placed on a pallet as shown in **Figure 4.22**. After lunch, the temperature of a one-litre bucket was recorded at 38.1ºC (**Figure 4.23**). The temperature of the plastic table that stood in the shade recorded a temperature of 35.1ºC whereas a part of the same table that stood in the sun recorded a temperature of 44.8ºC as shown in **Figure 4.24** and **Figure 4.25** respectively. This could be the reason for the high temperatures recorded during the Harvest and Transportation stage as discussed in section 4.7 for Farm B.

Figure 4.20: The main road leading to the blueberry fields
Source: Captured by the author for the purpose of the study

Figure 4.21: Pickers not following protocol by placing their one-litre buckets on the ground
Source: Captured by the author for the purpose of the study

Figure 4.22: Buckets lying on the ground and in the sun over lunch
Source: Captured by the author for the purpose of the study

Figure 4.23: Temperature recorded for a one-litre bucket after lunch
Source: Captured by the author for the purpose of the study

Figure 4.24: Temperature recorded for a table standing in the shade after lunch
Source: Captured by the author for the purpose of the study

Figure 4.25: Temperature recorded for a table standing in the sun after lunch
Source: Captured by the author for the purpose of the study

After harvest, a tractor-trailer was used to transport crates to the cold room. **Figure 4.26** shows the tractor-trailer arriving at the drop-off location at the cold room. During drop-off, a roof provided shade for the tractor-trailer as protocol dictates. The importance of a roof over the drop-off location cannot be emphasised enough, as a temperature of 34ºC was recorded at 12:19 even though water was sprayed on the concrete to cool the area. **Figure 4.27** shows that the building of pallets, pre-cooling and maintaining of temperature after pre-cooling took place in the same cold room. The cold room on the farm does not have separate rooms where the above-mentioned actions can take place. Therefore, protocol was not followed as it dictates that each action should take place in a separate room to achieve the best possible result. **Figure 4.28** shows that pre-cooling was applied to incomplete pallets. This is a problem, since blueberries containing field heat were placed on top of cooled blueberries to complete the pallet. This could cause fluctuations in temperature for the bottom half of the pallets. Furthermore, instead of recording the pulp temperature for the entire pallet, three blueberries were placed on the probe when the bottom half of the pallet was placed against the forced cooler. Therefore, as soon as the probe showed those three blueberries were on protocol temperature, pre-cooling was ceased for the pallet. **Figure 4.29** shows that employees did not always close the cold room door as protocol dictates. Section 4.8 showed that protocol temperatures for all three trials of Farm B were reached during the Packhouse stage and not during the Pre-Cooling stage as protocol dictates. The above-mentioned protocols not followed can all be factors contributing to the protocol temperature not being reached during the Pre-Cooling stage. Lastly, although this did not happen during the trials conducted on Farm B, an employee mentioned that if pallets are only due the following day, they do not implement forced cooling as the pallets will cool sufficiently overnight. However, this could have a negative effect on the blueberries as pre-cooling is essential to remove field heat as soon as possible.

Figure 4.26: Tractor-trailer standing in the shade at the drop-off location of the cold store
Source: Captured by the author for the purpose of the study

Figure 4.27: The building of pallets, pre-cooling and maintaining of temperature after pre-cooling taking place in the same cold room
Source: Captured by the author for the purpose of the study

Figure 4.28: Employee building pallets while pre-cooling is applied to incomplete pallets
Source: Captured by the author for the purpose of the study

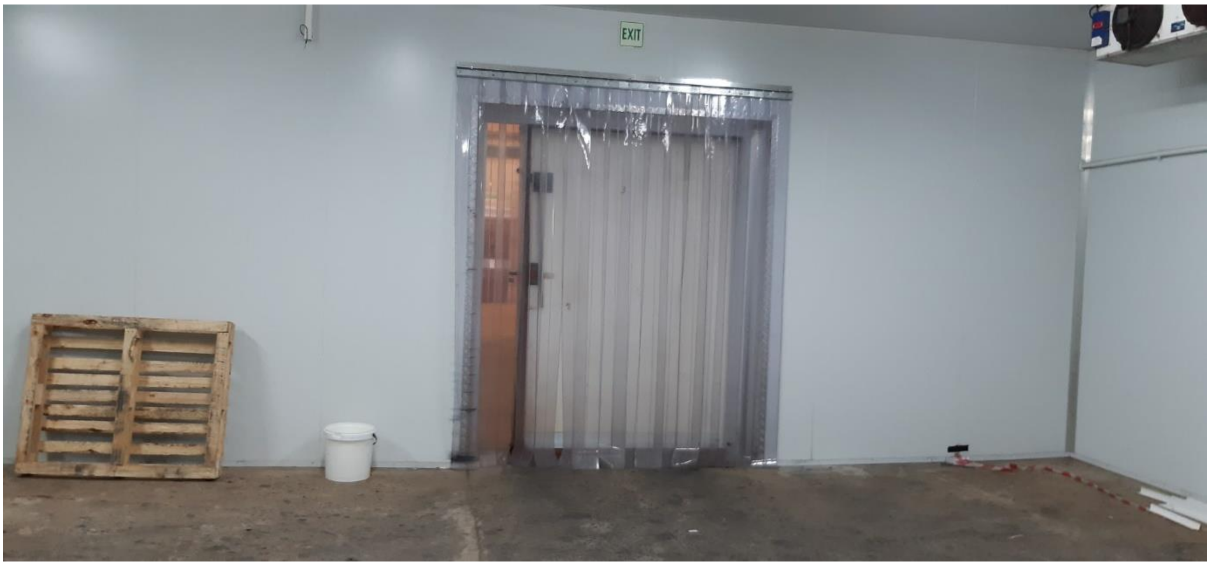


Figure 4.29: Cold room door not closed by employee
Source: Captured by the author for the purpose of the study

4.9.1.3. Farm C

Farm C deviated from the standard logistical processes used by Farm A and B during harvest. It was the only farm that made use of field packing. Pickers received lugs to fill during harvest as seen in **Figure 4.30**, instead of the usual one-litre buckets. Since the lugs were substantially bigger than the one-litre buckets, it was important that pickers harvest good quality blueberries, as it was more difficult to identify unhealthy fruit during QC. Furthermore, pickers were not required to walk to QC stations as Farm C made use of runners (**Figure 4.35**). These runners reduced any time wasted while walking. **Figure 4.31** shows that at the QC station, the blueberries were given a quick scan instead of the standard in-depth QC that took place during the other trials. In addition, the lugs were not emptied into crates at the QC station but transported as is to the cold room with a tractor-trailer (**Figure 4.32**). **Figure 4.33** shows that once the lugs were received at the cold room the blueberries were tipped into 4kg crates where an in-depth QC took place. Thereafter, pallets were built and moved into the cold room for cooling.

Figure 4.30: Pickers using lugs during harvest
Source: Captured by the author for the purpose of the study

Figure 4.31: Employee removing bad quality blueberries from the lugs
Source: Captured by the author for the purpose of the study

Figure 4.32: Tractor-trailer transporting lugs to the cold room
Source: Captured by the author for the purpose of the study

Figure 4.33: Employee emptying lugs into 4kg crates
Source: Captured by the author for the purpose of the study

All the roads leading to the cold room and blueberry fields were unpaved gravel roads. This caused a lot of dust when the lugs were transported to the packhouse. Due to erosion, the tractor-trailers also had a bumpy ride to the cold room that could cause bruising on the blueberries. At 10:45, during harvest, it began to rain. Pickers were instructed to immediately stop picking and instead cover the lugs (**Figure 4.34**). However, this instruction was not followed by every picker, as some continued picking when the picking team captain walked in the other direction. At 10:50, the rain stopped and at 10:53 pickers were instructed to continue picking. Protocol dictates that blueberries should remain dry during harvest. **Figure 4.35** shows how empty lugs stood in the sun. Furthermore, due to the absence of a gazebo, the lugs got wet during the rainfall. Protocol dictates that lugs should always be kept in the shade and be dry when used during harvest. **Figure 4.36** shows how the tractor-trailer stood in the sun during offloading, with no roof to provide shade as protocol dictates. After investigation, it was found that offloading normally occurs at the location where QC was carried out (**Figure 4.37**). The trials conducted on Farm C experienced a unique situation as on warm days QC and the building of pallets are carried out in the cold room. On the day of the trials, the temperature was described as cool enough, therefore, employees were instructed to conduct the QC and build pallets underneath the roof outside (**Figure 4.37**). However, at 16:00, the incoming afternoon sun caused lugs, incomplete pallets and the employees performing the QC to stand in the sun. **Figure 4.38** shows that the lugs standing in the sun recorded a temperature of 27.8ºC. **Figure 4.39** shows how an employee moved the finished pallet into the cold room. Protocol dictates that pallets should be pre-cooled by placing pallets against a forced cooling machine.

However, Farm C is not equipped with such a machine, therefore, pre-cooling is applied by placing the pallet in a cold room at 6ºC.

Figure 4.34: Pickers covering lugs with clothing to keep the blueberries dry
Source: Captured by the author for the purpose of the study

Figure 4.35: Lugs standing in the sun and runner carrying empty lugs to pickers
Source: Captured by the author for the purpose of the study

Figure 4.36: Tractor-trailer standing in the sun during offloading
Source: Captured by the author for the purpose of the study

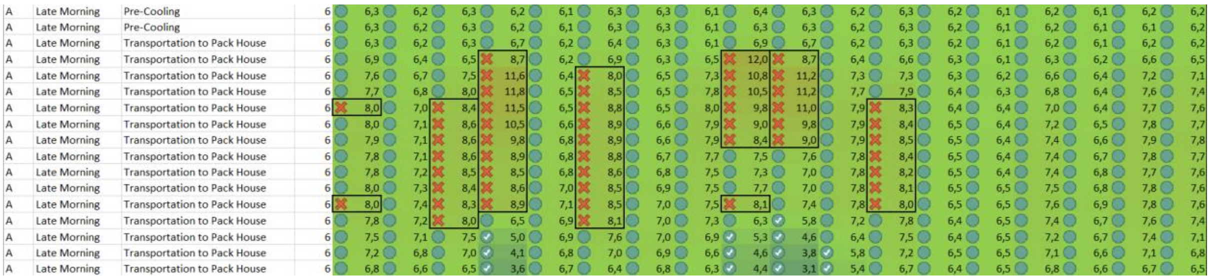
Figure 4.37: Employees performing QC where the tractor-trailer would normally stop for offload; lugs standing in the afternoon sun
Source: Captured by the author for the purpose of the study

Figure 4.38: Temperature of blueberries in lugs standing in the sun
Source: Captured by the author for the purpose of the study

Figure 4.39: Pallets moved into the cold room
Source: Captured by the author for the purpose of the study

4.9.1.4. Transportation to Packhouse

Farm A adhered to most of the protocols required when loading the pallets for transportation. The farm did not have a holding room that was separate from the pre-cooling room while loading the pallets. Even though the farm did have an airlock, the absence of a loading bay caused warm air to enter the cold room. **Figure 4.40** shows that for the Late Morning trials the rise in temperature happened at the beginning of the Transportation to Packhouse stage. Five temperature spikes and four temperature breaks were recorded as mentioned in section 4.7 (**Table 4.12**). Another possible reason for the rise in temperature could be that the reefer truck was not properly cooled before the loading of the pallets. It should be mentioned that the Early Morning and Afternoon trials did not experience the same extreme fluctuations in temperatures at the beginning of the Transportation to Packhouse stage, although temperatures did rise. This could be due to the Late Morning trials' pallet being the first to be loaded into the truck. When received at the packhouse the pallets were on protocol temperature.



A	Late Morning	Pre-Cooling	6	6,3	6,2	6,3	6,2	6,1	6,3	6,3	6,1	6,4	6,3	6,2	6,3	6,2	6,1	6,2	6,1	6,2	6,2
A	Late Morning	Pre-Cooling	6	6,3	6,2	6,3	6,2	6,1	6,3	6,3	6,1	6,3	6,3	6,2	6,3	6,2	6,1	6,2	6,1	6,1	6,2
A	Late Morning	Transportation to Pack House	6	6,3	6,2	6,3	6,7	6,2	6,4	6,3	6,1	6,9	6,7	6,2	6,3	6,2	6,1	6,2	6,1	6,2	6,2
A	Late Morning	Transportation to Pack House	6	6,9	6,4	6,5	8,7	6,2	6,9	6,3	6,5	12,0	8,7	6,4	6,6	6,3	6,1	6,3	6,2	6,6	6,5
A	Late Morning	Transportation to Pack House	6	7,6	6,7	7,5	11,6	6,4	8,0	6,5	7,3	10,8	11,2	7,3	7,3	6,3	6,2	6,6	6,4	7,2	7,1
A	Late Morning	Transportation to Pack House	6	7,7	6,8	8,0	11,8	6,5	8,5	6,5	7,8	10,5	11,2	7,7	7,9	6,4	6,3	6,8	6,4	7,6	7,4
A	Late Morning	Transportation to Pack House	6	8,0	7,0	8,4	11,5	6,5	8,8	6,5	8,0	9,8	11,0	7,9	8,3	6,4	6,4	7,0	6,4	7,7	7,6
A	Late Morning	Transportation to Pack House	6	8,0	7,1	8,6	10,5	6,6	8,9	6,6	7,9	9,0	9,8	7,9	8,4	6,5	6,4	7,2	6,5	7,8	7,7
A	Late Morning	Transportation to Pack House	6	7,9	7,1	8,6	9,8	6,8	8,9	6,6	7,9	8,4	9,0	7,9	8,5	6,5	6,4	7,4	6,6	7,9	7,8
A	Late Morning	Transportation to Pack House	6	7,8	7,1	8,6	8,9	6,8	8,8	6,7	7,7	7,5	7,6	7,8	8,4	6,5	6,4	7,4	6,7	7,8	7,7
A	Late Morning	Transportation to Pack House	6	7,8	7,2	8,5	8,5	6,8	8,6	6,8	7,5	7,3	7,0	7,8	8,2	6,5	6,4	7,4	6,8	7,7	7,6
A	Late Morning	Transportation to Pack House	6	8,0	7,3	8,4	8,6	7,0	8,5	6,9	7,5	7,7	7,0	7,8	8,1	6,5	6,5	7,5	6,8	7,8	7,6
A	Late Morning	Transportation to Pack House	6	8,0	7,4	8,3	8,9	7,1	8,5	7,0	7,5	8,1	7,4	7,8	8,0	6,5	6,5	7,6	6,9	7,8	7,6
A	Late Morning	Transportation to Pack House	6	7,8	7,2	8,0	6,5	6,9	8,1	7,0	7,3	6,3	5,8	7,2	7,8	6,4	6,5	7,4	6,7	7,6	7,4
A	Late Morning	Transportation to Pack House	6	7,5	7,1	7,5	5,0	6,9	7,6	7,0	6,9	5,3	4,6	6,4	7,5	6,4	6,5	7,2	6,7	7,4	7,1
A	Late Morning	Transportation to Pack House	6	7,2	6,8	7,0	4,1	6,8	7,0	6,9	6,6	4,6	3,8	5,8	7,2	6,5	6,5	7,1	6,6	7,1	6,8
A	Late Morning	Transportation to Pack House	6	6,8	6,6	6,5	3,6	6,7	6,4	6,8	6,3	4,4	3,1	5,4	6,7	6,4	6,5	6,8	6,6	6,7	6,5

Figure 4.40: Temperature spikes and temperature breaks that occurred for the Late Morning trials during the Transportation to Packhouse stage
Source: Compiled by the author for the purpose of the study

As mentioned earlier, insufficient pre-cooling was applied to all three trials for Farm B. Hence, protocol temperature was first reached during the Packhouse stage as shown in section 4.8. Farm B did not comply with any protocols regarding the loading of pallets. The farm does not have a holding room, separate from the building of pallets and pre-cooling rooms. In addition, during loading the farm did not have a loading bay or an airlock. **Figure 4.41** shows the rise in temperature at the beginning of the Transportation to Packhouse stage for the Afternoon trial. The same fluctuation in temperature occurred for all three trials. Furthermore, the farm made use of shared transportation. Although this is allowed, the transportation company did not reject the warm pallets from an unknown farm whilst in transit. When received at the packhouse, the pallets from Farm B recorded a temperature of 8.5ºC while the pallets of the unknown farm recorded a temperature of 14ºC.

B	Afternoon	Pre-Cooling	6	9,8	11,1	10,9	9,5	9,4	10,1	9,0	9,7	11,0	10,3	10,0	8,9	8,7	11,9	11,7	11,9	11,1
B	Afternoon	Pre-Cooling	6	9,8	11,0	10,8	9,4	9,4	10,1	9,0	9,6	11,0	10,3	10,0	8,9	8,7	11,8	11,6	11,8	11,1
B	Afternoon	Transportation to Pack House	6	9,8	11,0	10,8	9,4	9,4	10,0	8,9	9,6	11,0	10,2	10,0	8,8	8,6	11,8	11,5	11,8	11,1
B	Afternoon	Transportation to Pack House	6	9,7	11,0	10,8	9,3	9,4	9,9	8,9	9,5	10,9	10,1	9,9	8,8	8,6	11,8	11,5	11,7	11,0
B	Afternoon	Transportation to Pack House	6	9,7	10,9	10,7	9,3	9,3	9,9	8,9	9,5	10,8	10,1	9,8	8,8	8,6	11,7	11,5	11,7	10,9
B	Afternoon	Transportation to Pack House	6	9,7	10,8	10,7	9,3	9,2	9,9	8,9	9,5	10,8	10,1	9,9	8,7	8,6	11,6	11,4	11,6	10,9
B	Afternoon	Transportation to Pack House	6	10,0	10,8	10,6	9,3	9,4	9,8	8,9	9,9	10,7	10,1	9,9	8,8	8,8	11,6	11,4	11,5	10,9
B	Afternoon	Transportation to Pack House	6	10,8	10,8	10,7	9,6	9,7	10,1	10,0	10,4	10,8	10,4	10,0	10,2	9,9	11,9	11,4	11,5	11,1
B	Afternoon	Transportation to Pack House	6	10,6	10,8	10,7	9,7	9,9	10,3	10,8	10,2	10,8	10,8	10,1	10,9	10,8	11,8	11,3	11,5	11,1
B	Afternoon	Transportation to Pack House	6	10,5	10,8	10,8	9,9	10,2	10,5	10,5	10,5	10,8	10,6	10,1	11,0	11,3	11,7	11,3	11,5	11,0
B	Afternoon	Transportation to Pack House	6	10,5	10,8	10,8	10,0	10,2	10,4	10,3	10,5	10,8	10,6	10,1	10,6	11,1	11,6	11,2	11,4	10,9
B	Afternoon	Transportation to Pack House	6	10,5	10,8	10,8	10,1	10,1	10,4	10,1	10,5	10,7	10,5	10,1	10,5	10,8	11,6	11,2	11,4	10,9
B	Afternoon	Transportation to Pack House	6	10,5	10,8	10,8	10,2	10,0	10,3	10,0	10,4	10,7	10,4	10,0	10,4	10,6	11,4	11,2	11,4	10,9
B	Afternoon	Transportation to Pack House	6	10,4	10,8	10,8	10,2	9,9	10,3	10,0	10,3	10,7	10,4	10,0	10,2	10,5	11,5	11,2	11,4	10,9
B	Afternoon	Transportation to Pack House	6	10,3	10,8	10,7	10,2	9,7	10,3	9,9	10,1	10,7	10,4	10,0	10,4	10,4	11,4	11,2	11,3	10,8
B	Afternoon	Transportation to Pack House	6	10,2	10,8	10,7	10,1	9,7	10,3	9,9	10,0	10,7	10,3	9,9	10,4	10,4	11,3	11,1	11,2	10,7
B	Afternoon	Transportation to Pack House	6	10,1	10,7	10,6	10,0	9,7	10,3	9,8	10,0	10,7	10,3	9,8	10,4	10,3	11,2	11,0	11,2	10,6
B	Afternoon	Transportation to Pack House	6	10,0	10,7	10,6	10,0	9,7	10,3	9,8	9,9	10,6	10,2	9,8	10,4	10,2	11,1	11,0	11,2	10,5
B	Afternoon	Transportation to Pack House	6	10,0	10,6	10,6	9,9	9,7	10,3	9,8	9,9	10,6	10,2	9,7	10,3	10,1	11,0	11,0	11,1	10,4
B	Afternoon	Transportation to Pack House	6	10,0	10,6	10,6	9,9	9,7	10,3	9,6	9,9	10,5	10,1	9,6	10,2	10,1	10,9	11,0	11,1	10,4

Figure 4.41: Temperature rising during the beginning stages of the Transportation to Packhouse stage for the Afternoon trial
Source: Compiled by the author for the purpose of the study

As Farm C does not have separate rooms for building pallets, pre-cooling and holding after pre-cooling is completed, which means that protocol was not followed. In addition, Farm C has a loading bay, but does not have an airlock. As mentioned in section 4.8, the Early Morning trial only reached protocol temperature during Forced Cooling stage. This was a result of a decision to fill an available truck the same day as harvest, instead of waiting for the pallet to reach protocol temperature during pre-cooling. During loading, the thermometer of the truck indicated a temperature of 13ºC. This could be a contributing factor to the rise in temperature at the beginning of the Transportation to Packhouse stage observed in **Figure 4.42**.

C	Early Morning	Pre-Cooling	6	15,5	17,1	10,2	11,9	14,2	12,4	18,8	18,5	15,1	16,3	7,8	7,5	15,6	16,0	6,1	4,1	12,8	14,3
C	Early Morning	Pre-Cooling	6	15,6	17,0	10,3	11,7	13,9	12,2	18,1	18,0	14,9	16,1	7,6	7,4	15,6	16,0	6,0	4,3	12,6	14,1
C	Early Morning	Pre-Cooling	6	15,3	16,7	10,3	11,5	13,6	11,9	16,6	18,0	14,6	15,8	7,4	7,1	15,4	16,0	5,8	4,1	12,1	14,0
C	Early Morning	Pre-Cooling	6	15,2	16,5	10,2	11,3	13,3	11,7	16,9	18,0	14,4	15,6	7,4	7,0	15,3	15,5	5,6	4,3	11,7	13,8
C	Early Morning	Transportation to Pack House	6	15,1	16,5	10,3	11,2	13,2	11,5	16,8	17,5	14,3	15,5	7,4	6,9	15,1	15,5	5,8	4,8	11,6	13,6
C	Early Morning	Transportation to Pack House	6	15,2	16,3	10,4	11,2	13,0	11,4	17,3	18,0	14,1	15,4	7,6	7,1	15,0	15,5	5,9	5,6	11,8	13,6
C	Early Morning	Transportation to Pack House	6	15,4	16,3	10,6	11,4	12,9	11,4	17,9	18,0	14,3	15,4	8,4	7,6	15,1	15,5	6,4	6,9	12,6	13,6
C	Early Morning	Transportation to Pack House	6	15,4	16,3	11,2	11,1	12,9	9,8	17,9	17,5	14,1	13,8	8,1	7,4	15,1	15,5	7,6	6,1	12,7	13,6
C	Early Morning	Transportation to Pack House	6	15,4	16,1	11,6	10,8	12,9	8,9	17,9	17,5	14,0	12,3	8,1	7,3	15,1	15,5	7,6	6,0	12,5	13,5
C	Early Morning	Transportation to Pack House	6	15,4	16,0	11,9	10,6	12,8	8,5	17,9	17,5	13,9	11,2	8,1	7,3	15,1	16,0	7,7	6,1	12,4	13,4
C	Early Morning	Transportation to Pack House	6	15,5	16,0	12,1	10,4	12,7	8,3	17,6	17,5	13,8	10,2	8,1	7,3	15,1	16,0	7,8	6,3	12,3	13,4
C	Early Morning	Transportation to Pack House	6	15,5	15,9	12,4	10,2	12,6	8,2	17,6	17,5	13,6	9,7	8,1	7,3	15,3	16,0	7,7	6,4	12,3	13,3
C	Early Morning	Transportation to Pack House	6	15,4	15,9	12,5	10,0	12,5	7,9	17,5	17,0	13,5	9,3	8,1	7,3	15,1	16,0	7,6	6,5	12,2	13,1
C	Early Morning	Transportation to Pack House	6	15,4	15,8	12,6	9,8	12,4	7,8	17,5	17,0	13,3	9,0	8,3	7,3	15,0	16,0	7,6	6,6	12,2	13,0
C	Early Morning	Transportation to Pack House	6	15,4	15,8	12,6	9,7	12,2	7,6	17,4	17,0	13,1	8,7	8,3	7,3	14,9	16,0	7,5	6,8	12,0	13,0
C	Early Morning	Transportation to Pack House	6	15,3	15,7	12,6	9,5	12,0	7,5	17,4	17,0	12,9	8,4	8,4	7,3	14,9	16,0	7,5	6,8	11,9	12,9
C	Early Morning	Transportation to Pack House	6	15,2	15,6	12,7	9,3	11,9	7,3	17,3	17,0	12,8	8,2	8,4	7,3	14,8	16,0	7,4	6,9	11,9	12,8

Figure 4.42: Temperature rising during the beginning stages of the Transportation to Packhouse stage for the Early Morning trial
Source: Compiled by the author for the purpose of the study

All pallets from the farms in the Western Cape were transported to a mutual packhouse. The packhouse adhered to all the protocol requirements during offloading. **Figure 4.43** shows both the outside and inside view of the loading bay and airlock used at this packhouse to offload pallets.

Figure 4.43: The outside and inside view of the loading bay and airlock used at this packhouse to offload pallets
Source: Captured by the author for the purpose of the study

4.9.1.5. Packhouse

The same logistical procedures were used for Farms A and B. **Figure 4.44** shows the holding room where pallets received from the farms were weighed, temperatures measured, and inspection carried out by the packhouse. Protocol dictates that the holding room maintain a temperature of 6ºC. The researcher recorded a temperature of 6.3ºC prior to an expected offloading from an independent farm. After offloading, a temperature of 8.3ºC was recorded. Although the temperature quickly recovered, this phenomenon showed the importance of a loading bay and airlock. After inspection, the pallets were moved to a cold room to maintain the temperature before packaging commenced. **Figure 4.45** shows that the cold room maintained a temperature of 4.9ºC.

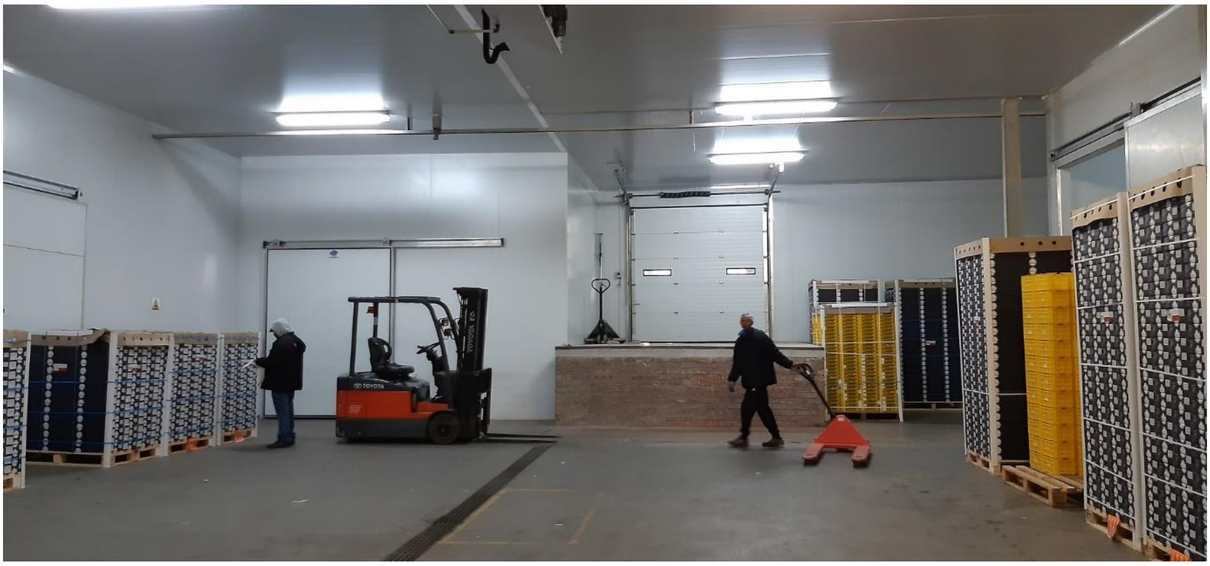


Figure 4.44: Holding room in the packhouse where pallets are weighed, temperatures are measured, and inspection was performed
Source: Captured by the author for the purpose of the study

Figure 4.45: Cold room in the packhouse where pallets are held before packaging commenced
Source: Captured by the author for the purpose of the study

Protocol dictates that employees must transport and use one pallet at a time to provide blueberries for the sorting machine. In addition, the temperature of the packing room should be set at 6ºC. These protocols were not followed as more than one pallet was often observed in the packing room and temperatures higher than 6ºC were recorded. **Figure 4.46** shows an employee tipping a crate of blueberries onto the packing and sorting machine (left) and employees sorting blueberries (right). **Figure 4.47** shows that a temperature of 9.6ºC was recorded inside the packing room. In addition, the figure displays how pallets are assembled and boxes labelled by employees. **Figure 4.48** shows a clear rise in temperature and two temperature spikes for the Early Morning trial of Farm A. In addition, the Late Morning trial also experienced a temperature spike, while a rise in temperature was identified for the

Afternoon trial. Due to the insufficient pre-cooling on Farm B, the rise in temperature while in the packing room was not recorded as a temperature break but was apparent on the data for all three trials (**Figure 4.49**).

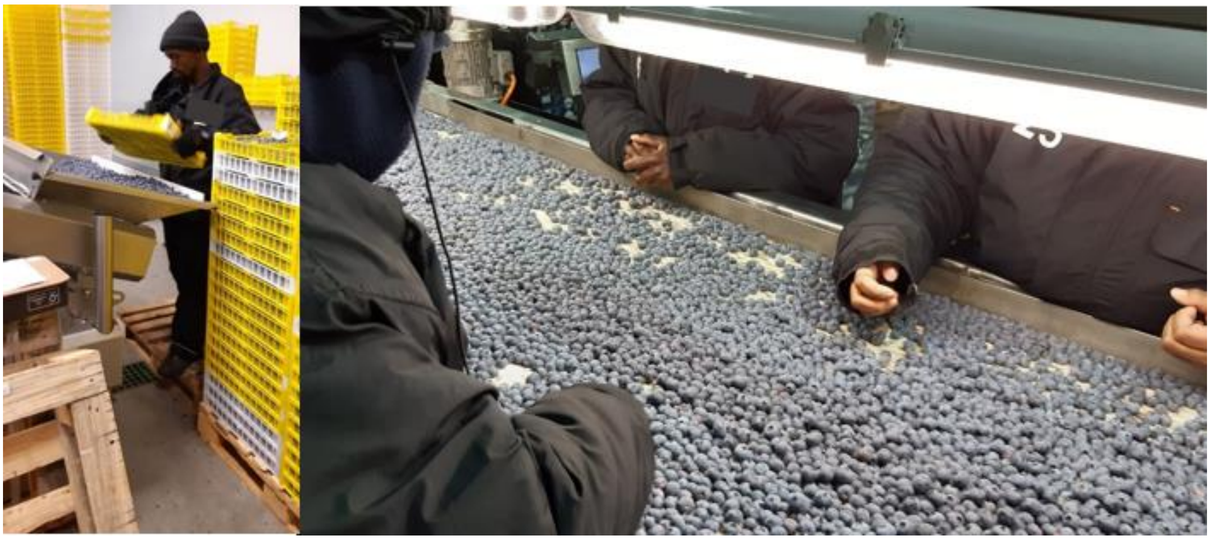


Figure 4.46: Employee tipping a crate of blueberries onto the packing and sorting machine (left) and employees sorting blueberries (right)
Source: Captured by the author for the purpose of the study

Figure 4.47: Temperature measured in the packing room
Source: Captured by the author for the purpose of the study

A	Early Morning	Transportation to Pack House	6	5,8	4,3	6,3	6,3	6,0	6,0	5,4	6,2	6,5	6,3	6,0	6,3	4,3	5,5	6,1	4,7	6,1	4,5
A	Early Morning	Transportation to Pack House	6	5,8	4,4	6,3	6,2	6,0	6,0	5,3	6,2	6,5	6,3	6,0	6,3	4,2	5,4	6,1	4,7	6,1	4,5
A	Early Morning	Pack House	6	5,7	4,4	6,2	6,1	6,0	5,9	5,2	6,1	6,5	6,2	6,0	6,2	4,2	5,3	6,0	4,7	6,1	4,4
A	Early Morning	Pack House	6	5,9	4,8	6,2	6,2	6,0	5,9	5,4	6,2	6,5	6,1	6,0	6,2	4,1	5,3	6,0	5,0	6,1	4,6
A	Early Morning	Pack House	6	5,9	4,9	6,1	6,1	5,9	5,8	5,5	6,2	6,5	5,9	6,0	6,1	3,9	4,8	5,9	5,0	6,1	4,6
A	Early Morning	Pack House	6	5,9	4,9	6,0	6,1	5,9	5,9	5,4	6,2	6,5	6,0	6,0	6,1	3,9	5,0	5,9	5,0	6,1	4,6
A	Early Morning	Pack House	6	5,9	4,9	6,0	5,8	6,0	5,9	5,3	6,1	6,4	6,1	6,0	6,1	3,8	5,0	5,9	5,0	6,1	4,4
A	Early Morning	Pack House	6	5,9	5,0	6,0	5,7	6,0	5,9	5,3	6,1	6,5	6,2	6,0	6,1	3,8	5,0	5,9	5,0	6,1	4,4
A	Early Morning	Pack House	6	5,9	5,0	5,8	5,4	5,9	5,9	5,2	6,0	6,4	6,2	5,9	6,0	3,7	5,0	5,9	5,0	5,9	4,3
A	Early Morning	Pack House	6	5,9	5,0	5,8	5,4	5,9	5,7	5,2	6,0	6,4	6,1	5,9	6,0	3,6	5,0	5,9	5,0	5,9	4,2
A	Early Morning	Pack House	6	5,7	5,1	5,8	5,4	5,8	5,6	5,2	6,0	6,4	6,0	5,9	6,0	3,5	5,0	5,8	5,0	5,9	4,2
A	Early Morning	Pack House	6	5,7	5,1	5,8	5,4	5,8	5,6	5,3	6,0	6,4	6,0	5,8	6,0	3,6	5,1	5,7	5,1	5,9	4,2
A	Early Morning	Pack House	6	5,8	5,6	6,0	5,8	6,6	6,0	5,7	6,2	6,2	6,3	5,9	6,0	4,0	5,8	6,0	5,6	6,1	4,6
A	Early Morning	Pack House	6	6,4	6,7	6,7	7,0	7,7	7,5	7,2	8,0	9,2	6,5	6,3	6,3	4,6	6,3	7,6	6,3	6,5	5,1
A	Early Morning	Pack House	6	6,1	6,4	6,4	6,6	6,8	7,0	6,4	7,2	7,5	7,5	7,1	7,1	6,5	7,4	7,9	7,2	6,9	5,9
A	Early Morning	Pack House	6	5,6	5,7	6,1	6,1	6,0	6,4	5,9	5,9	6,6	6,9	6,6	6,6	5,4	7,0	7,2	6,7	6,6	5,4
A	Early Morning	Pack House	6	5,2	5,0	5,9	5,8	5,6	6,1	5,7	5,2	6,1	6,5	6,3	6,6	4,9	6,6	6,9	6,3	6,4	5,3
A	Early Morning	Pack House	6	5,1	4,8	5,8	5,6	5,4	5,9	5,5	5,0	5,9	6,5	6,3	6,6	4,7	6,5	6,7	6,3	6,4	5,2
A	Early Morning	Pack House	6	5,1	4,8	5,8	5,5	5,5	5,7	5,5	5,0	5,8	6,4	6,2	6,5	4,6	6,5	6,5	6,2	6,4	5,2
A	Early Morning	Pack House	6	5,1	4,9	5,8	5,5	5,6	5,5	5,4	5,1	5,7	6,2	6,1	6,1	4,4	6,3	6,2	6,2	6,2	5,1
A	Early Morning	Pack House	6	5,1	5,0	5,8	5,4	5,7	5,5	5,5	5,2	5,7	6,2	6,0	6,0	4,3	6,1	6,0	6,1	6,1	5,1
A	Early Morning	Pack House	6	5,2	5,0	5,7	5,4	5,8	5,4	5,5	5,2	5,7	6,2	6,0	5,8	4,2	6,0	5,9	6,0	6,1	5,1

Figure 4.48: Rise in temperature and temperature break recorded for the Early Morning trial of Farm A when in the packing room
Source: Compiled by the author for the purpose of the study

B	Early Morning	Pack House	6	6,3	6,7	7,6	7,0	7,6	7,5	7,6	6,9	6,3	5,4	7,7	6,6	7,5	6,9	6,7	7,8	7,8
B	Early Morning	Pack House	6	6,3	6,7	7,7	7,0	7,7	7,5	7,6	6,9	6,2	5,5	7,7	6,9	7,5	6,9	6,8	7,8	7,9
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,0	7,7	7,5	7,6	7,0	6,2	5,6	7,7	7,0	7,4	6,9	6,8	7,7	7,9
B	Early Morning	Pack House	6	6,2	6,7	7,8	7,0	7,7	7,5	7,6	7,0	6,2	5,7	7,7	7,1	7,6	6,9	6,8	7,8	7,9
B	Early Morning	Pack House	6	6,2	6,7	7,8	7,0	8,1	8,0	7,6	7,0	6,2	5,7	7,7	7,8	7,9	7,1	7,2	8,1	8,2
B	Early Morning	Pack House	6	6,2	6,7	7,8	7,0	8,3	8,2	7,6	7,0	6,3	5,8	7,7	8,0	8,1	7,8	7,9	8,2	8,3
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,0	9,4	8,2	7,6	7,0	6,3	5,8	7,7	8,1	8,1	8,1	8,2	8,3	8,4
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,0	8,7	8,2	7,6	7,0	6,4	5,9	7,7	8,1	8,1	8,2	8,2	8,2	8,3
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,0	8,5	8,2	7,6	7,0	6,4	6,0	7,7	8,1	8,1	8,2	8,2	8,2	8,3
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,0	8,3	8,1	7,6	7,1	6,4	6,0	7,7	8,1	8,0	8,1	8,2	8,1	8,2
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,0	8,2	7,9	7,6	7,1	6,4	6,0	7,7	8,0	7,9	8,1	8,1	8,0	8,2
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,1	8,1	7,8	7,6	7,1	6,5	6,1	7,7	8,0	7,9	8,0	8,0	8,0	8,1
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,1	8,0	7,7	7,6	7,1	6,5	6,1	7,7	7,9	7,8	7,9	7,9	7,9	8,1
B	Early Morning	Pack House	6	6,3	6,7	7,7	7,1	8,0	7,7	7,6	7,1	6,5	6,2	7,7	7,8	7,8	7,9	7,9	7,9	8,0
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,1	7,8	7,6	7,6	7,1	6,6	6,2	7,7	7,8	7,7	7,8	7,8	7,8	8,0
B	Early Morning	Pack House	6	6,3	6,7	7,8	7,1	7,8	7,5	7,6	7,1	6,6	6,2	7,6	7,7	7,6	7,7	7,7	7,7	7,9
B	Early Morning	Pack House	6	6,3	6,7	7,7	7,1	7,6	7,4	7,5	7,1	6,6	6,3	7,6	7,6	7,5	7,7	7,6	7,6	7,8
B	Early Morning	Pack House	6	6,3	6,7	7,7	7,1	7,5	7,3	7,5	7,1	6,6	6,3	7,6	7,6	7,4	7,6	7,4	7,5	7,7
B	Early Morning	Pack House	6	6,3	6,7	7,7	7,1	7,4	7,3	7,5	7,1	6,6	6,3	7,6	7,5	7,2	7,5	7,3	7,4	7,6

Figure 4.49: Rise in temperature recorded for the Early Morning trial of Farm B when in the packing room
Source: Compiled by the author for the purpose of the study

After a pallet was strapped and labelled it was moved back to the holding room (**Figure 4.50**). Here the pallet was once again weighed and inspected. However, this inspection was carried out by an employee from the Perishable Products Export Control Board (PPECB). **Figure 4.51** shows how the PPECB selects boxes for inspection (left). After inspection, the PPECB provides each box with a stamp as well as each pallet with a sticker. Once all the paperwork was complete the pallet was moved to a cold room, to maintain the temperature, before being transported to the cold store (**Figure 4.52**). However, all three trials for Farm A experienced very low temperatures whilst in the cold room. Instead of maintaining temperatures, chilling injury spikes and chilling injury breaks were recorded here. **Figure 4.53** shows that a temperature of -1.8ºC was recorded for the Afternoon trial, while a minimum temperature of -2.2ºC was recorded for the Early Morning trial.

Figure 4.50: Employee moving the finished pallet from the packing room to the holding room
Source: Captured by the author for the purpose of the study

Figure 4.51: PPECB selecting boxes for inspection (left) and providing each box with a PPECB stamp after inspection (right)
Source: Captured by the author for the purpose of the study

Figure 4.52: Pallets being moved into a cold room
Source: Captured by the author for the purpose of the study

A	Afternoon	Pack House		6	0,7	0,5	0,6	0,7	1,0	2,7	1,4	0,9	1,1	0,5	0,4	0,7	1,0	2,1	0,9	1,7	3,1	1,0
A	Afternoon	Pack House		6	0,5	1,0	0,9	1,0	1,0	2,9	1,7	1,1	1,4	1,0	0,9	1,1	1,3	2,3	1,2	1,9	3,1	1,2
A	Afternoon	Pack House		6	0,0	-0,6	-0,6	-0,3	-0,2	2,7	1,0	0,1	0,8	-0,1	-0,5	-0,1	0,2	2,1	0,2	1,6	3,1	0,5
A	Afternoon	Pack House		6	0,9	0,8	0,8	0,9	1,2	2,7	1,4	1,1	1,2	0,7	0,5	0,9	1,2	2,1	1,0	1,7	3,0	1,1
A	Afternoon	Pack House		6	-0,1	-0,2	-0,3	0,1	-0,4	2,8	1,4	0,4	1,2	0,6	0,2	0,4	0,7	2,2	0,7	1,9	3,1	0,8
A	Afternoon	Pack House		6	0,3	-0,1	-0,1	0,2	0,3	2,7	1,1	0,4	0,9	0,1	-0,1	0,3	0,5	2,0	0,5	1,6	3,0	0,7
A	Afternoon	Pack House		6	1,0	1,1	1,1	1,2	1,4	2,7	1,5	1,2	1,3	0,9	0,8	1,1	1,3	2,1	1,2	1,8	3,0	1,2
A	Afternoon	Pack House		6	-0,3	-1,0	-1,2	-0,8	-1,0	2,7	1,0	-0,3	0,9	-0,1	-0,6	-0,3	0,0	2,1	0,2	1,7	3,0	0,3
A	Afternoon	Pack House		6	0,6	0,3	0,3	0,5	0,7	2,6	1,2	0,7	1,0	0,4	0,2	0,5	0,8	2,0	0,7	1,6	3,0	0,8
A	Afternoon	Pack House		6	0,8	1,2	1,3	1,2	1,5	2,7	1,5	1,3	1,3	1,1	1,0	1,2	1,4	2,1	1,2	1,8	3,0	1,2
A	Afternoon	Pack House		6	-0,7	$\boxed{-1,54}$	$\boxed{-1,8}$	-1,1	$\boxed{-1,6}$	2,7	0,9	-0,6	0,9	-0,2	-1,1	-0,7	-0,2	2,1	0,0	1,6	3,0	0,2
A	Afternoon	Pack House		6	-0,1	-0,8	-1,1	-0,3	-0,4	2,9	1,0	0,0	1,0	-0,1	-0,8	-0,2	0,2	2,3	0,3	1,6	3,0	0,5
A	Afternoon	Pack House		6	0,2	-0,3	-0,5	0,1	0,1	2,9	1,2	0,4	1,2	0,2	-0,5	0,2	0,6	2,6	0,7	1,9	3,0	0,8
A	Afternoon	Transportation to Forced Cooler		6	0,3	0,0	-0,2	0,4	0,5	3,0	1,4	0,6	1,3	0,4	-0,1	0,4	0,9	2,7	0,9	2,0	3,0	1,0
A	Afternoon	Transportation to Forced Cooler		6	0,5	0,1	0,0	0,5	0,7	3,0	1,5	0,7	1,4	0,5	0,0	0,4	1,0	2,8	1,1	2,1	3,0	1,1

Figure 4.53: Low temperatures reached for the Afternoon trial of Farm A while in the cold room
Source: Compiled by the author for the purpose of the study

Farm C made use of field packing, and therefore, bypassed all the packhouse procedures except for one. At the packhouse the pallets were offloaded in the holding room where it was subsequently weighed, and the temperature measured. In addition, the pallets stood in the holding room until the process was completed before being transported to the cold store.

4.9.1.6. Transportation to Forced Cooling

The same protocols apply for this stage as used for the Transportation to Packhouse stage. **Figure 4.54** shows how pallets were offloaded at the cold store. No fluctuation in temperature for any of the farms in the Western Cape occurred during this stage. This proves true as the cold store was situated at the same facility as the packhouse. As mentioned in section 4.6, the procedures used for Farms A and B differ from the procedures used for Farm C during this stage. Field-packed blueberries, as in the case with Farm C, was inspected in the holding room of the forced cooling facility during the Transportation to Forced Cooling stage (**Figure 4.55**). **Figure 4.56** shows the employees of the packhouse performing an inspection to test for sugar levels and firmness of the blueberries.

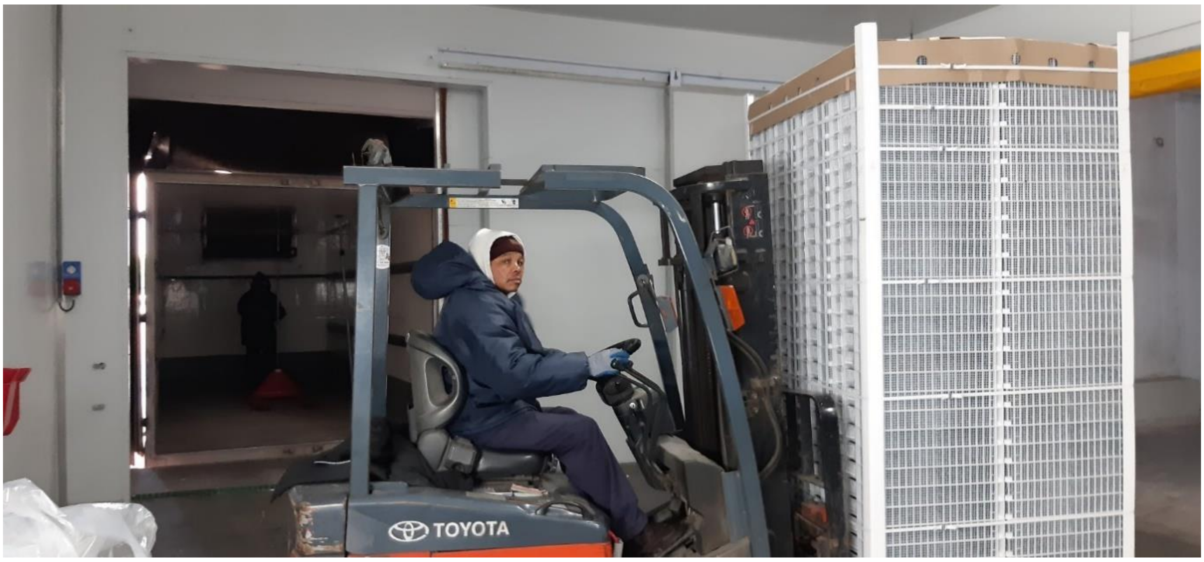


Figure 4.54: Pallets received from the packhouse being offloaded at the cold store
Source: Captured by the author for the purpose of the study

Figure 4.55: Pallets standing in the holding room of the cold store
Source: Captured by the author for the purpose of the study

Figure 4.56: Employees doing inspection for the pallets of Farm C
Source: Captured by the author for the purpose of the study

4.9.1.7. Forced Cooling

As discussed in section 4.7, Farm A recorded a total of 26 temperature spikes during the Forced Cooling stage. **Figure 4.57** shows some of the temperature spikes recorded for the Late Morning trial of Farm A. Furthermore, Farm A recorded a total of 303 chilling injury spikes and two chilling injury breaks during the Forced Cooling stage. **Figure 4.58** shows some of the chilling injury spikes recorded for the Afternoon trial of Farm A. It should be mentioned that most of the chilling injury spikes occurred at the beginning of forced cooling. A single iButton® for the Early Morning trial of Farm A recorded both chilling injury breaks. These chilling injury spikes and breaks could be due to the low temperatures that were maintained in the cold room of the packhouse.

A	Late Morning	Forced Cooling	0	1,3	1,8	0,7	1,2	1,1	1,6	1,7	1,6	1,4	0,9	0,9	1,8	1,8	0,8	1,1	1,3	1,3	1,1
A	Late Morning	Forced Cooling	0	0,9	0,0	0,6	0,5	0,5	0,7	0,6	0,5	0,7	0,7	0,6	0,4	0,4	0,7	0,6	0,7	0,7	0,6
A	Late Morning	Forced Cooling	0	0,8	0,3	0,5	0,4	0,5	0,6	0,5	0,4	0,7	0,6	0,5	0,5	0,4	0,6	0,5	0,6	0,5	0,6
A	Late Morning	Forced Cooling	0	0,8	0,5	0,5	0,5	0,5	0,6	0,6	0,4	0,7	0,6	0,5	0,6	0,5	0,6	0,5	0,6	0,5	0,6
A	Late Morning	Forced Cooling	0	1,3	2,3	0,7	1,3	1,2	1,7	1,9	1,7	1,4	0,8	0,9	2,1	2,2	0,8	1,1	1,2	1,3	1,2
A	Late Morning	Forced Cooling	0	0,6	-0,9	0,5	-0,1	0,1	0,0	-0,1	-0,3	-0,1	0,6	0,3	-0,4	-0,4	0,5	0,2	0,2	0,2	0,1
A	Late Morning	Forced Cooling	0	-0,3	-1,1	0,2	-0,7	-0,6	-1,0	-1,1	-1,3	-0,3	0,1	-0,3	-0,8	-1,1	0,0	-0,5	-0,7	-0,8	-0,4
A	Late Morning	Forced Cooling	0	0,4	0,8	0,4	0,4	0,4	0,5	0,5	0,4	0,8	0,5	0,3	0,9	0,7	0,3	0,4	0,5	0,3	0,5
A	Late Morning	Forced Cooling	0	1,0	1,3	0,6	0,9	0,9	1,2	1,2	1,1	1,2	0,8	0,7	1,4	1,3	0,7	0,8	1,0	0,9	0,9
A	Late Morning	Forced Cooling	0	1,3	1,8	0,7	1,1	1,1	1,5	1,7	1,5	1,4	0,9	0,9	1,7	1,7	0,8	1,1	1,3	1,2	1,1
A	Late Morning	Forced Cooling	0	0,8	-0,6	0,6	0,2	0,3	0,4	0,2	0,0	0,1	0,7	0,5	-0,1	-0,2	0,6	0,4	0,4	0,3	0,3
A	Late Morning	Forced Cooling	0	-0,1	-0,4	0,2	-0,4	-0,3	-0,5	-0,6	-0,8	0,0	0,3	-0,1	-0,3	-0,4	0,1	-0,2	-0,4	-0,4	-0,2

Figure 4.57: Some of the temperature spikes recorded for the Late Morning trial of Farm A during the Forced Cooling stage
Source: Compiled by the author for the purpose of the study

A	Afternoon	Transportation to Forced Cooler	6	0,5	0,2	0,1	0,5	0,7	3,0	1,5	0,9	1,5	0,6	0,1	0,5	1,0	2,8	1,1	2,1	3,1	1,2
A	Afternoon	Transportation to Forced Cooler	6	0,6	0,2	0,1	0,6	1,0	3,0	1,4	1,0	1,6	1,1	0,4	1,0	1,6	2,9	1,4	2,3	3,2	1,4
A	Afternoon	Transportation to Forced Cooler	6	0,7	0,4	0,4	0,7	1,4	3,3	1,7	1,3	1,7	1,1	0,5	1,1	1,8	3,0	1,5	2,3	3,4	1,4
A	Afternoon	Forced Cooling	0	0,8	0,5	0,5	0,9	1,5	3,3	1,9	1,4	1,8	0,9	0,5	0,9	1,7	3,1	1,5	2,3	3,5	1,4
A	Afternoon	Forced Cooling	0	1,0	0,6	0,6	0,9	2,1	3,2	2,0	1,7	2,0	0,9	0,7	0,9	1,9	3,3	1,6	2,3	3,6	1,4
A	Afternoon	Forced Cooling	0	1,0	0,7	0,7	1,0	2,0	3,2	2,2	1,8	2,1	0,9	0,7	0,9	1,9	3,3	1,6	2,4	3,6	1,4
A	Afternoon	Forced Cooling	0	1,1	0,7	0,7	1,1	2,0	3,2	2,2	1,8	2,1	0,9	0,7	0,9	1,9	3,3	1,6	2,4	3,6	1,4
A	Afternoon	Forced Cooling	0	1,1	0,7	0,7	1,1	1,5	3,2	2,2	1,6	2,0	0,4	0,7	1,1	1,7	3,0	1,6	2,1	2,8	1,3
A	Afternoon	Forced Cooling	0	1,1	0,5	0,6	1,1	1,4	2,9	2,0	1,4	1,7	0,8	0,7	1,1	1,5	2,8	1,6	2,2	2,8	1,3
A	Afternoon	Forced Cooling	0	0,0	0,0	0,2	0,7	0,5	2,1	1,4	0,6	0,0	0,3	0,2	0,5	0,5	2,0	1,0	1,8	3,0	0,4
A	Afternoon	Forced Cooling	0	-0,8	-1,0	-0,9	-0,2	-0,6	1,2	0,7	-0,5	-0,9	-0,7	-0,8	-0,4	-0,5	1,1	0,1	0,8	2,7	-0,6
A	Afternoon	Forced Cooling	0	-1,2	-1,4	-1,3	-0,6	-1,0	0,8	0,4	-1,0	-1,4	-1,1	-1,3	-0,8	-0,8	0,8	-0,3	0,4	2,5	-1,0
A	Afternoon	Forced Cooling	0	-1,5	-1,7	-1,6	-0,8	-1,4	0,5	0,1	-1,3	-1,7	-1,4	-1,6	-1,0	-1,1	0,4	-0,5	0,1	2,4	-1,4
A	Afternoon	Forced Cooling	0	-1,7	-2,0	-1,8	-1,0	-1,6	0,3	-0,2	-1,7	-1,9	-1,7	-1,8	-1,3	-1,3	0,3	-0,8	-0,1	2,2	-1,6
A	Afternoon	Forced Cooling	0	-1,8	-2,1	-2,0	-1,2	-1,8	0,2	-0,3	-1,8	-2,1	-1,8	-2,0	-1,4	-1,4	0,1	-0,9	-0,3	2,1	-1,7
A	Afternoon	Forced Cooling	0	-1,9	-2,2	-2,2	-1,3	-1,9	0,0	-0,4	-1,9	-2,2	-2,0	-2,2	-1,5	-1,6	0,0	-1,1	-0,5	2,0	-1,9
A	Afternoon	Forced Cooling	0	-2,1	-2,4	-2,2	-1,5	-2,0	-0,1	-0,5	-2,0	-2,3	-2,1	-2,3	-1,7	-1,7	-0,1	-1,2	-0,6	1,9	-2,0
A	Afternoon	Forced Cooling	0	-0,1	-0,4	-0,7	-0,3	-0,3	0,6	0,1	-0,6	-0,2	-0,4	-0,8	-0,5	-0,3	0,3	-0,4	0,2	1,9	-0,3
A	Afternoon	Forced Cooling	0	-0,1	0,3	0,2	0,5	0,6	1,3	0,7	0,4	0,1	0,4	0,2	0,4	0,4	0,9	0,4	1,0	2,1	0,3
A	Afternoon	Forced Cooling	0	-1,4	-1,5	-1,3	-0,8	-1,1	0,3	-0,2	-1,1	-1,6	-1,2	-1,3	-0,8	-1,1	0,3	-0,5	0,0	1,9	-1,3
A	Afternoon	Forced Cooling	0	-1,8	-2,0	-1,8	-1,2	-1,7	0,0	-0,5	-1,7	-2,1	-1,7	-1,9	-1,3	-1,47	-0,1	-1,0	-0,5	1,8	-1,7
A	Afternoon	Forced Cooling	0	-2,0	-2,3	-2,2	-1,5	-1,9	-0,3	-0,7	-2,0	-2,3	-2,0	-2,2	-1,7	-1,7	-0,3	-1,2	-0,7	1,6	-2,0
A	Afternoon	Forced Cooling	0	-1,4	-2,1	-2,1	-1,5	-1,9	-0,4	-0,8	-2,0	-2,0	-2,0	-2,2	-1,7	-1,7	-0,4	-1,3	-0,8	1,5	-1,9
A	Afternoon	Forced Cooling	0	0,3	0,2	-0,1	0,0	0,3	0,7	0,3	-0,1	0,2	0,1	-0,3	0,0	0,1	0,4	-0,1	0,5	1,7	0,2
A	Afternoon	Forced Cooling	0	-0,3	0,2	0,2	0,3	0,5	1,0	0,5	0,4	-0,1	0,3	0,2	0,4	0,2	0,8	0,3	0,9	1,8	0,2
A	Afternoon	Forced Cooling	0	-1,49	-1,6	-1,5	-1,0	-1,2	0,0	-0,4	-1,2	-1,7	-1,3	-1,4	-1,0	-1,2	0,0	-0,7	-0,3	1,6	-1,4
A	Afternoon	Forced Cooling	0	-1,4	-2,0	-1,9	-1,3	-1,7	-0,4	-0,7	-1,7	-2,0	-1,8	-2,0	-1,5	-1,6	-0,4	-1,1	-0,7	1,4	-1,8
A	Afternoon	Forced Cooling	0	0,3	0,2	-0,1	0,0	0,3	0,7	0,2	0,0	0,2	0,1	-0,3	0,0	0,1	0,3	-0,1	0,4	1,5	0,2

Figure 4.58: Some of the chilling injuries recorded for the Afternoon trial of Farm A during the Forced Cooling stage
Source: Compiled by the author for the purpose of the study

No temperature breaks, chilling injury spikes or chilling injury breaks were recorded for the trials of Farm B during the Forced Cooling stage, as discussed in section 4.7. However, a total of 132 temperature spikes were recorded for Farm B during the Forced Cooling stage. **Figure 4.59** shows some of the temperature spikes recorded for the Early Morning trials of Farm B during the Forced Cooling stage.

B	Early Morning	Forced Cooling	0	0,7	0,7	0,7	0,7	0,6	0,7	0,4	0,5	1,0	0,6	0,9	0,4	0,7	0,6	0,9	0,8	0,8
B	Early Morning	Forced Cooling	0	1,3	1,0	1,2	1,2	0,9	1,2	0,8	1,0	1,5	1,0	1,5	0,9	1,0	1,0	1,4	1,3	1,3
B	Early Morning	Forced Cooling	0	0,2	0,7	0,8	0,7	1,0	0,6	0,7	0,5	0,3	0,7	0,3	0,7	0,8	0,9	0,3	0,6	0,7
B	Early Morning	Forced Cooling	0	-0,7	-0,1	-0,3	-0,3	0,5	-0,5	0,1	-0,4	-0,7	-0,1	-0,8	0,0	0,3	0,5	-0,7	-0,6	-0,3
B	Early Morning	Forced Cooling	0	-0,3	0,1	-0,1	0,0	0,6	-0,1	0,3	-0,1	-0,3	0,2	-0,4	0,2	0,6	0,6	-0,2	-0,3	0,0
B	Early Morning	Forced Cooling	0	0,0	0,3	0,1	0,2	0,7	0,1	0,4	0,2	0,1	0,3	-0,1	0,4	0,7	0,7	0,1	0,0	0,3
B	Early Morning	Forced Cooling	0	4,1	2,0	2,6	2,7	0,9	2,9	1,1	2,5	5,1	2,2	4,9	1,7	1,5	1,2	4,2	3,3	3,1
B	Early Morning	Forced Cooling	0	1,7	1,7	2,3	1,9	1,7	2,2	1,6	2,0	1,7	2,0	1,7	1,8	1,7	1,6	1,8	2,1	2,1
B	Early Morning	Forced Cooling	0	-0,6	0,1	0,0	-0,1	0,8	-0,3	0,4	-0,2	-0,7	0,1	-0,7	0,2	0,5	0,6	-0,6	-0,3	-0,2
B	Early Morning	Forced Cooling	0	-1,1	-0,4	-0,7	-0,7	0,2	-1,0	-0,2	-1,0	-1,1	-0,7	-1,2	-0,4	-0,1	0,1	-1,1	-1,1	-0,8
B	Early Morning	Forced Cooling	0	0,5	0,6	0,5	0,5	0,5	0,4	0,4	0,3	0,8	0,4	0,7	0,3	0,6	0,6	0,6	0,5	0,6
B	Early Morning	Forced Cooling	0	1,1	1,0	1,1	1,1	0,9	1,1	0,8	1,0	1,4	0,9	1,3	0,8	1,0	1,0	1,2	1,2	1,3
B	Early Morning	Forced Cooling	0	0,8	1,0	1,2	1,0	1,1	1,1	0,9	1,0	0,9	1,0	0,9	0,9	1,0	1,1	1,0	1,1	1,1
B	Early Morning	Forced Cooling	0	-1,1	-0,2	-0,4	-0,5	0,5	-0,7	0,0	-0,7	-1,1	-0,4	-1,1	-0,2	0,1	0,3	-0,9	-0,7	-0,6

Figure 4.59: Some of the temperature spikes recorded for the Early Morning trials of Farm B during the Forced Cooling stage
Source: Compiled by the author for the purpose of the study

As previously mentioned, the pallets of the Early Morning trial were transported to the packhouse one day prior to the pallets of the Late Morning and Afternoon trials for Farm C. Therefore, the pallets from the Early Morning trial underwent forced cooling a day before the pallets from the Late Morning and Afternoon trials. However, instead of the Early Mornings trials' pallets being shipped for exportation, they remained in the forced cooler. In addition, the pallets of the Late Morning and Afternoon trials were placed in the same forced cooling tunnel as the pallet for the Early Morning trial. Therefore, the pallets from the Early Morning trial experienced forced cooling on two occasions. As discussed in section 4.7, Farm C recorded a total of 46 temperature spikes. Thirty-two (32) temperature spikes and seven temperature breaks were recorded, for the Early Morning trial from Farm C. **Figure 4.60** shows the rise in temperature recorded for the Early Morning trial from Farm C. Most of the temperature spikes and breaks recorded for the Early Morning trial occurred after the first forced cooling session and before forced cooling was applied for a second time. After investigation, it was found that the fluctuations in temperature were recorded while the pallets of the Late Morning and Afternoon trials were being moved into the forced cooling tunnel. **Figure 4.61** shows how pallets were moved into the forced cooling tunnel and covers were used to improve airflow.

C	Early Morning	Forced Cooling		0	1,9	1,5	2,0	2,2	1,7	2,1	1,4	0,5	1,6	2,1	2,0	1,6	1,6	1,5	1,9	2,3	1,8	1,3
C	Early Morning	Forced Cooling		0	1,9	1,5	2,0	2,2	1,7	2,1	1,5	0,5	1,6	2,1	2,1	2,0	1,6	1,5	1,9	2,4	1,9	1,3
C	Early Morning	Forced Cooling		0	1,8	1,4	1,8	2,1	1,7	2,1	1,5	0,5	1,5	2,0	1,9	1,8	1,5	1,5	1,9	2,1	1,8	1,1
C	Early Morning	Forced Cooling		0	1,8	1,4	1,6	1,9	1,6	2,0	1,5	0,5	1,5	2,0	1,9	1,5	1,5	1,5	1,7	1,9	1,6	1,0
C	Early Morning	Forced Cooling		0	1,7	1,3	1,5	1,9	1,5	1,9	1,5	0,5	1,5	2,0	1,9	1,5	1,5	1,0	1,7	1,9	1,5	1,0
C	Early Morning	Forced Cooling		0	1,8	1,4	1,6	1,9	1,6	1,9	1,5	0,5	1,5	2,0	1,9	1,5	1,5	1,0	1,7	2,0	1,5	1,1
C	Early Morning	Forced Cooling		0	1,8	1,4	1,6	2,0	1,6	1,9	1,5	0,5	1,5	2,0	2,0	1,6	1,6	1,0	1,8	2,0	1,6	1,1
C	Early Morning	Forced Cooling		0	2,0	1,4	2,1	2,7	1,6	2,0	2,0	1,5	1,6	2,0	2,9	1,8	2,0	1,5	1,9	2,8	1,9	1,1
C	Early Morning	Forced Cooling		0	2,6	1,6	3,0	2,7	1,9	2,1	2,0	1,5	1,8	2,1	2,6	1,8	2,1	1,5	2,3	2,6	2,4	1,4
C	Early Morning	Forced Cooling		0	2,3	1,6	2,3	2,3	1,9	2,1	1,8	1,0	1,6	2,1	2,3	1,6	2,0	1,5	2,1	2,3	2,0	1,3
C	Early Morning	Forced Cooling		0	2,1	1,5	1,8	2,1	1,8	2,0	1,6	1,0	1,5	2,0	2,0	1,4	1,9	1,5	1,9	2,0	1,7	1,1
C	Early Morning	Forced Cooling		0	1,9	1,5	1,5	1,8	1,7	1,9	1,6	0,5	1,5	1,9	1,9	1,4	1,8	1,5	1,7	1,9	1,5	1,0
C	Early Morning	Forced Cooling		0	1,8	1,5	1,3	1,6	1,6	1,9	1,6	0,5	1,5	1,8	1,8	1,3	1,6	1,5	1,6	1,8	1,4	0,9
C	Early Morning	Forced Cooling		0	1,6	1,5	1,1	1,5	1,6	1,8	1,5	0,5	1,5	1,8	1,8	1,3	1,5	1,0	1,6	1,6	1,3	0,9
C	Early Morning	Forced Cooling		0	1,6	1,5	0,9	1,4	1,5	1,8	1,5	0,5	1,4	1,8	1,6	1,3	1,4	1,0	1,5	1,5	1,2	0,8
C	Early Morning	Forced Cooling		0	1,4	1,5	0,9	1,3	1,4	1,7	1,5	0,5	1,4	1,7	1,5	1,1	1,4	1,0	1,4	1,4	1,2	0,8
C	Early Morning	Forced Cooling		0	1,4	1,5	0,7	1,2	1,4	1,7	1,5	0,5	1,4	1,6	1,5	1,1	1,3	1,0	1,3	1,4	1,1	0,8
C	Early Morning	Forced Cooling		0	1,3	1,4	0,7	1,1	1,3	1,6	1,4	0,5	1,3	1,6	1,4	1,1	1,3	1,0	1,3	1,3	1,0	0,6
C	Early Morning	Forced Cooling		0	1,2	1,3	0,6	1,0	1,3	1,6	1,4	0,0	1,3	1,6	1,4	1,0	1,1	1,0	1,2	1,3	1,0	0,6
C	Early Morning	Forced Cooling		0	1,2	1,3	0,6	0,9	1,2	1,5	1,4	0,0	1,1	1,5	1,3	1,0	1,1	0,5	1,2	1,1	1,0	0,6
C	Early Morning	Forced Cooling		0	1,1	1,3	0,5	0,9	1,1	1,5	1,3	0,0	1,1	1,5	1,3	1,0	1,0	0,5	1,1	1,1	0,9	0,6
C	Early Morning	Forced Cooling		0	1,1	1,2	0,4	0,8	1,1	1,4	1,3	0,0	1,1	1,5	1,1	0,9	1,0	0,5	1,1	1,0	0,8	0,5
C	Early Morning	Forced Cooling		0	1,0	1,2	0,4	0,7	1,0	1,4	1,3	0,0	1,0	1,4	1,1	0,9	0,9	0,5	1,0	1,0	0,8	0,5
C	Early Morning	Forced Cooling		0	0,9	1,1	0,3	0,7	0,9	1,3	1,1	0,0	1,0	1,3	1,0	0,9	0,9	0,5	0,9	0,9	0,7	0,5
C	Early Morning	Forced Cooling		0	0,9	1,0	0,2	0,6	0,9	1,3	1,1	0,0	0,9	1,3	1,0	0,8	0,8	0,5	0,9	0,9	0,7	0,4
C	Early Morning	Forced Cooling		0	0,8	1,0	0,2	0,5	0,8	1,3	1,0	0,0	0,9	1,3	0,9	0,8	0,8	0,5	0,8	0,8	0,7	0,4

Figure 4.60: Some of the temperature spikes and breaks recorded for the Early Morning trials of Farm C during the Forced Cooling stage
Source: Compiled by the author for the purpose of the study

Figure 4.61: Pallets being moved into the forced cooling tunnel and covers rolled on to pallets to improve airflow
Source: Captured by the author for the purpose of the study

4.9.2. Gauteng

The cold rooms on the farms in Gauteng are well established compared to the farms in the Western Cape. All three farms are equipped with state-of-the-art cold room facilities. The cold room facility of Farm E is seen as the benchmark by Company X. Furthermore, Farm F is the only farm that makes use of a cooling trailer, powered by a generator. This cooling trailer is used to transport crates from the field to the cold room. In addition, pre-cooling was applied by placing pallets inside a container shaped cooler and then applying forced-air cooling (**Figure 4.62**). All the other farms made use of the conventional forced-air cooling system as can be seen in **Figure 4.63**.

Figure 4.62: Container shaped forced-air cooler used during pre-cooling for Farm F
Source: Captured by the author for the purpose of the study

Figure 4.63: Conventional forced-air cooling used during pre-cooling for all the farms, except Farm F
Source: Captured by the author for the purpose of the study

4.9.2.1. Farm D

On the day of the trial it was warm, with temperatures averaging between the high twenties and low thirties. As mentioned in section 4.5, a technical error resulted in the researcher having to perform two trials for Farm D. The images as well as observations discussed in this section were collected during trial D1. **Figure 4.64** shows an employee picking blueberries. The rope tied around the picker's waist is used to hang multiple one-litre buckets from, ensuring that the picker does not place the buckets on the ground. Two, one-litre buckets, were filled while the third was used to discard blueberries damaged during picking. **Figure 4.65** shows that the road most travelled between the field and cold room is covered with peach pips. This ensures a smooth ride and prevents the unnecessary occurrence of dust. Although not all roads are covered with peach pips, Farm D is in the process of improving their roads. Protocol was not followed during lunch, as empty crates and one-litre buckets were left standing in the sun (**Figure 4.66**). **Figure 4.67** shows the importance of following the required protocol, since the empty crates and one-litre buckets recorded temperatures of 31.2ºC and 34.6ºC, respectively.

Figure 4.64: Employee picking blueberries
Source: Captured by the author for the purpose of the study

Figure 4.65: Road covered with peach pips to prevent unnecessary dust
Source: Captured by the author for the purpose of the study

Figure 4.66: Empty crates and one-litre buckets left standing in the sun during lunch
Source: Captured by the author for the purpose of the study

Figure 4.67: Temperature of crates (left) and one-litre buckets (right) standing in the sun
Source: Captured by the author for the purpose of the study

Figure 4.68 shows the tractor-trailers used to transport the blueberries from the field to the cold room. In addition, the figure shows that the offloading area is equipped with a roof to provide shade. Instead of parking in the shade next to the tractor-trailer busy with offloading, the other driver parked behind the front tractor-trailer, in the sun. As a result, protocol was not followed. **Figure 4.69** shows that a temperature of 17.2ºC and 35.4ºC were recorded in the shade and sun, respectively. Although the argument can be made that the second tractor-trailer was only briefly stationary in the sun, any rise in temperature could have a negative effect on the quality of blueberries.

Figure 4.68: A tractor-trailer waiting in the sun instead of in the shade provided by the roof during offloading
Source: Captured by the author for the purpose of the study

Figure 4.69: Temperatures recorded of the concrete floor at the offloading site in the shade (left) versus in the sun (right)
Source: Captured by the author for the purpose of the study

The different sections in the cold room of Farm D are displayed in **Figure 4.70**. After offloading, the crates were moved into the packing room (right), where pallets are usually built before being moved into the pre-cooling room (left). However, during trial D1, the harvest had just begun, and therefore, pallets were built in the pre-cooling room (**Figure 4.70**). Protocol was not followed as protocol dictates that pallets should be completed in the packing room before being moved to the pre-cooling room. **Figure 4.71** shows that the pre-cooling (left) and packing (right) rooms recorded a temperature of 5.9ºC and 12ºC, respectively. In addition, while building the pallets, the door between the packing and the pre-cooling room was open for extended periods (**Figure 4.70**). This is not ideal as the warm air could cause a fluctuation in temperature. Subsequently, after pre-cooling, the pallets were moved through the door (**Figure 4.72**), to the holding room.

Figure 4.70: The different sections in a cold room
Source: Captured by the author for the purpose of the study

Figure 4.71: The different sections in a cold room
Source: Captured by the author for the purpose of the study

Figure 4.72: Pre-cooling being applied to pallets, and the door leading to the holding room
Source: Captured by the author for the purpose of the study

4.9.2.2. Farm E

Out of the six farms where trials were conducted, Farm E was undoubtedly the largest. It is noteworthy to mention that on the day of the trial it was very hot, with temperatures averaging in the thirties. **Figure 4.73** shows the gravel road most travelled between the field and cold room. Farm E made use of a water bowser to prevent the occurrence of dust on the road. Although this is an improvement from what the other farms did, Farm E should also focus on employing the same method on the main roads between the fields. Furthermore, most of the QC tables had gazebos, as protocol dictates. The shade the gazebo provides for the QC table is clearly seen in **Figure 4.74**. In addition, the trailer was used to protect empty crates and crates filled with blueberries, from the sun. Although the QC tables were equipped with gazebos, **Figure 4.74** shows that not all protocols were followed, as the doors of the trailer were seldom closed. In addition, protocol was not followed, since the empty crates were removed from the trailer and placed on the table (in the sun), long before they were used.

Figure 4.73: Gravel road most travelled between the field and the cold room
Source: Captured by the author for the purpose of the study

Figure 4.74: QC table and trailer used to transport crates
Source: Captured by the author for the purpose of the study

The importance of positioning crates, tables, and one-litre buckets in the shade cannot be emphasised enough. A temperature of 22.8ºC was recorded (in the shade) for a crate that was half covered with shade, while a temperature of 29.7ºC was recorded for the same crate, in the area exposed in the sun. Furthermore, **Figure 4.75** compares the different temperatures recorded for a plastic table versus a steel table in the sun. In addition, **Figure 4.76** compares the different temperatures recorded when a steel table was half covered with shade while the other half stood in the sun. The plastic table recorded a temperature of 34ºC. The half of the steel table that stood in the sun recorded a temperature of 40.6ºC while the half that stood in the shade recorded a temperature of 22.6ºC. The above-mentioned finding seems plausible, as steel is a better conductor of heat than plastic is.

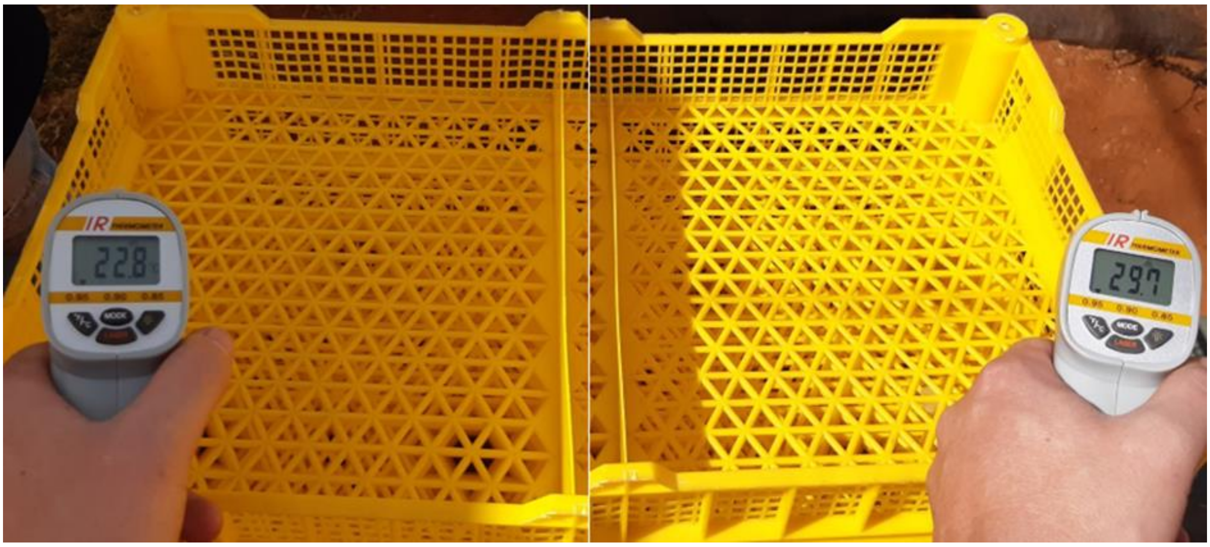


Figure 4.75: The temperatures recorded of the same crate in the shade (left) and in the sun (right)
Source: Captured by the author for the purpose of the study

Figure 4.76: The temperatures recorded simultaneously for a plastic table in the sun, steel table in the sun and steel table in the shade
Source: Captured by the author for the purpose of the study

Figure 4.77 shows a QC table without a gazebo. After investigation it was found that the table was previously equipped with a gazebo, but it broke due to strong wind. This was a common occurrence on all farms forming part of this study. It is important to mention that the employee placed an empty crate below the crates filled with blueberries, attempting to prevent the heat generated from the steel table from affecting the blueberries. **Figure 4.78** shows that the steel table featured in **Figure 4.77** recorded a temperature of 47.7ºC. This could be the reason for the highest temperature of 40.9ºC recorded during the Late Morning trial as discussed in section 4.7.

Figure 4.77: QC table without a gazebo
Source: Captured by the author for the purpose of the study

Figure 4.78: Temperature recorded of a steel table standing in the sun
Source: Captured by the author for the purpose of the study

During the Early Morning trial, all the crates that underwent QC, were placed in the trailer at 10:32. At 11:10, instead of instructing a tractor to transport the crates to the cold room, the supervisor made the decision to continue harvesting to fill another trailer. Upon investigation, it was revealed that the reason for the decision was to save time as it was almost lunch. After the tractor-trailer arrived at the cold room at 12:18, more than three tractor-trailers stood in a queue (**Figure 4.79**). This left the researcher perplexed, as the queue could have been avoided. The exact same event occurred during the Late Morning trial. At 15:15, the crates that were approved by the QC employees were placed in the trailer, ready to be transported to the cold room. However, the transportation of the crates of the Late Morning trial were delayed like with the Early Morning trial. Instead at 17:41, the crates of the Late Morning and Afternoon trials arrived together at the cold room. Once again, a queue of more than three tractor-trailers were observed at the cold room. As discussed in section 4.6, Farm E spent the longest time during the Harvest and Transportation stage, with an average of 6.22 hours. Far longer than the protocol time of one hour. **Figure 4.80** shows the crates being offloaded in a shaded area as protocol dictates. A pulp temperature of 29ºC was recorded for a single blueberry during offloading **(Figure 4.81**). Furthermore, **Figure 4.82** shows an employee moving the crates into the cold room. The door of the cold room was open and closed the entire time, as protocol dictates. **Figure 4.83** shows pallets being built in the packing room. A temperature of 8ºC was recorded in the packing room, even though protocol dictates that the packing rooms' temperature should be 6ºC. From the packing room, the pallet was moved into the pre-cooling room to apply forced-air cooling (**Figure 4.84**). Thereafter, the pallet was moved into the holding room that was set at 4ºC (**Figure 4.85**).

Figure 4.79: Tractor-trailers waiting in a queue to offload crates at the cold room
Source: Captured by the author for the purpose of the study

Figure 4.80: Employee offloading crates at the cold room
Source: Captured by the author for the purpose of the study

Figure 4.81: Pulp temperature recorded of a blueberry during offload
Source: Captured by the author for the purpose of the study

Figure 4.82: Crate being moved into the cold room after offloading
Source: Captured by the author for the purpose of the study

Figure 4.83: Pallets being built in the packing room
Source: Captured by the author for the purpose of the study

Figure 4.84: Forced-air cooling applied during pre-cooling
Source: Captured by the author for the purpose of the study

Figure 4.85: Holding room pallets were moved to after pre-cooling was applied
Source: Captured by the author for the purpose of the study

4.9.2.3. Farm F

Due to a tight schedule in Gauteng, the trials for Farms E and F were conducted on the same day. The trial for Farm E was conducted by the researcher, while an employee of Company X volunteered to conduct the trial for Farm F. It is noteworthy to mention that on the day of the trials it was very hot, with temperatures averaging in the thirties. **Figure 4.86** shows the unpaved gravel road used to travel between the field and cold room. Protocol was not followed as this road was not sprayed with water, resulting in a great deal of dust encountered while driving. **Figure 4.87** shows that Farm F made use of buckets smaller than the conventional one-litre buckets used by most of the other farms during harvest. In addition, the buckets hung around the picker's neck instead of their waist. Each picker also received a stand, which could carry three crates (**Figure 4.88**). Furthermore, **Figure 4.89** shows that empty crates were left in the sun instead of the shade, as protocol dictates.

Figure 4.86: Gravel road used to travel between the field and cold room
Source: Captured by the author for the purpose of the study

Figure 4.87: Buckets used during picking
Source: Captured by the author for the purpose of the study

Figure 4.88: Stands used to hold crates during picking
Source: Captured by the author for the purpose of the study

Figure 4.89: Empty crates standing in the sun
Source: Captured by the author for the purpose of the study

After the crates filled with blueberries were approved by employees performing QC, they were placed in the generator-powered trailer applying cooling within ten minutes (**Figure 4.90**). The trailer was, however, not equipped with a roof during offloading, as protocol dictates. **Figure 4.91** shows the packing room where pallets were built before placing them in the container shaped forced-air cooler. **Figure 4.92** shows the pre-cooling being applied to remove field heat from the pallets. After pre-cooling was complete, the pallets were moved into the holding room.

Figure 4.90: Generator-powered trailer used to cool and transport the crates
Source: Captured by the author for the purpose of the study

Figure 4.91: Packing room where pallets were built before being placed in the pre-cooler
Source: Captured by the author for the purpose of the study

Figure 4.92: Forced-air cooling used during pre-cooling
Source: Captured by the author for the purpose of the study

4.9.2.4. Transportation to Packhouse

For the trials conducted in Gauteng, no temperature spikes or breaks were recorded during the Transportation to Packhouse stage. Compared to the farms in the Western Cape, the Gauteng farms had some distinct differences that resulted in a more efficient cold chain. Section 4.8, discussed how all farms except for the Late Morning and Afternoon trials for Farm D2, reached protocol temperature during the Pre-Cooling stage. Furthermore, all three farms in Gauteng were equipped with a holding room that was separate from the pre-cooling and packing rooms, to maintain temperatures after pre-cooling was applied. All three farms were also equipped with a loading bay and an air-lock system. Although no temperature spikes or breaks were recorded, the packhouse has some improvements that can be made to their offloading facilities.

The packhouse does not have a loading bay and requires a forklift to offload the pallets (**Figure 4.93**). In addition, the packhouse shares the facilities with another packhouse, that packs products that are not as temperature sensitive as blueberries. Thus, the door on the right was never closed during the day as the other packhouse employees might not be aware of the importance of preventing fluctuations in temperature (**Figure 4.94**). During offloading of the pallets at the packhouse, temperatures of 13ºC and 15ºC were recorded for Farms E and F, respectively. Although the packhouse is equipped with an air-lock system it was, however, not used during offloading (**Figure 4.94**). After investigation, it was found that the airlock was too high and wide for the reefer truck to fit properly. **Figure 4.95** shows that the holding room has limited space, hence the forklift would not be able to turn freely during the peak hours of the day when the holding room is filled with pallets.

Figure 4.93: A reefer truck reversing into the offloading area at the packhouse
Source: Captured by the author for the purpose of the study

Figure 4.94: An employee offloading a pallet at the packhouse while the door on the right was not closed
Source: Captured by the author for the purpose of the study

Figure 4.95: The airlock system not used during offloading (left) and an employee offloading a pallet in the holding room (right)
Source: Captured by the author for the purpose of the study

4.9.2.5. Packhouse

Figure 4.96 shows the holding room in the packhouse, where the pallets received from Farms D-F were weighed, temperatures measured, and inspections carried out. Protocol dictates that the holding room maintain a temperature of 6ºC. However, protocol was not followed since a temperature of 8.3ºC was recorded after offloading was complete. This rise in temperature could be the consequence of multiple doors not being closed during offloading (**Figure 4.97**). Both doors leading to the outside remained open, as seen in **Figure 4.97**. A few minutes later, after all the doors were closed, the temperature of the holding rooms recovered to 5ºC. In all three trials for Farm E an evident rise in temperature was observed, whilst the pallets were in the holding room. Both the Late Morning and Afternoon trials for Farm E recorded temperature breaks. **Figure 4.98** shows a distinct rise in temperature as well as four temperature breaks recorded for the Late Morning trial for Farm E. In addition, a clear rise in temperature for the Early Morning trial for Farm F was also observed. **Figure 4.99** shows that one temperature spike was recorded for the Late Morning trial for Farm F when the pallets were situated in the holding room. Furthermore, the door of the cold room was not closed during offloading, which can lead to a fluctuation in temperatures for pallets waiting to be packed (**Figure 4.100**). After inspection, the pallets were moved to a cold room to maintain temperature before packaging commenced (**Figure 4.100**). In this cold room, a temperature of 1.8ºC was recorded by the researcher. **Figure 4.100** shows that the cold room is built in a "L" shape, therefore, dividing the packing room on the left and the cold room, where completed pallets are held, on the right. This is not ideal as the shortest route from the inspection room to the packing room is through the two cold rooms. On multiple occasions the doors linking the three rooms were not closed, as protocol dictates (**Figure 4.101**).

Figure 4.96: The holding room in the packhouse where pallets are weighed, temperatures measured, and inspection performed
Source: Captured by the author for the purpose of the study

Figure 4.97: Multiple doors (indicated with a red square) not closed during the offloading of pallets
Source: Captured by the author for the purpose of the study

E	Late Morning	Pack House	6	4,3	7,2	4,1	4,3	6,6	4,7	4,9	6,8	4,1	3,5	4,2	4,0	5,5	6,8	3,7	4,1	6,2	4,0
E	Late Morning	Pack House	6	4,3	7,6	4,1	4,3	7,0	4,8	4,9	7,2	4,1	3,6	4,2	3,9	5,8	7,1	3,7	4,1	6,3	4,0
E	Late Morning	Pack House	6	4,4	7,9	4,1	4,3	7,4	4,9	5,1	7,5	4,2	3,6	4,3	3,9	6,0	7,5	3,7	4,1	6,6	4,0
E	Late Morning	Pack House	6	4,5	8,4	4,1	4,5	7,8	5,2	5,1	7,8	4,2	3,7	4,2	3,9	6,0	7,9	3,7	4,1	6,7	4,0
E	Late Morning	Pack House	6	4,7	8,7	4,1	4,5	8,1	5,1	5,2	8,2	4,3	3,8	4,2	3,9	5,8	8,2	3,7	4,1	6,5	4,0
E	Late Morning	Pack House	6	4,8	8,9	4,1	4,6	8,2	5,0	5,2	8,3	4,4	4,0	4,2	4,0	5,5	8,4	3,8	4,2	6,2	4,0
E	Late Morning	Pack House	6	5,0	9,0	5,0	4,6	8,4	5,1	5,4	8,4	4,4	4,1	4,4	4,1	5,4	8,6	3,8	4,2	6,2	4,1
E	Late Morning	Pack House	6	5,2	9,1	4,6	4,6	8,5	5,3	5,4	8,5	4,6	4,2	5,0	4,2	5,7	8,4	3,9	4,2	6,5	4,1
E	Late Morning	Pack House	6	5,4	9,2	4,6	4,6	8,5	5,2	5,4	8,5	4,7	4,5	5,2	4,4	5,5	8,5	3,9	4,2	6,4	4,2
E	Late Morning	Pack House	6	5,5	9,2	4,7	4,7	8,5	5,1	5,4	8,5	4,7	4,6	5,3	4,5	5,3	8,6	4,0	4,3	6,4	4,3
E	Late Morning	Pack House	6	5,6	9,1	4,6	4,7	8,4	5,2	5,4	8,5	4,8	4,8	5,4	4,6	5,2	8,6	4,2	4,4	6,3	4,3
E	Late Morning	Pack House	6	5,7	9,1	4,6	4,7	8,4	5,2	5,4	8,4	4,8	5,0	5,4	4,7	5,1	8,6	4,3	4,4	6,2	4,4
E	Late Morning	Pack House	6	5,8	8,9	4,6	4,7	8,4	5,2	5,4	8,4	4,9	5,0	5,4	4,8	5,1	8,5	4,3	4,4	6,2	4,4
E	Late Morning	Pack House	6	5,9	8,9	4,6	4,7	8,3	5,2	5,4	8,4	4,9	5,1	5,3	4,9	5,1	8,5	4,4	4,4	6,3	4,5
E	Late Morning	Pack House	6	5,9	8,8	4,6	4,7	8,2	5,1	5,4	8,4	4,9	5,1	5,2	4,9	5,0	8,4	4,4	4,5	6,3	4,5
E	Late Morning	Pack House	6	6,0	8,7	4,8	4,7	8,2	5,2	5,5	8,3	5,1	5,1	5,1	4,9	5,2	8,1	4,4	4,5	6,4	4,5
E	Late Morning	Pack House	6	6,0	8,6	4,9	4,7	8,0	5,2	5,5	8,3	5,1	5,1	5,1	4,9	5,1	7,9	4,4	4,6	6,4	4,6
E	Late Morning	Pack House	6	6,1	8,4	4,9	4,7	8,0	5,3	5,5	8,2	5,1	5,2	5,1	4,9	5,0	7,7	4,5	4,6	6,4	4,6
E	Late Morning	Pack House	6	6,1	8,2	4,9	4,8	8,0	5,3	5,5	8,2	5,2	5,2	5,1	5,0	5,0	7,6	4,5	4,6	6,4	4,8
E	Late Morning	Pack House	6	6,2	8,0	4,9	4,8	7,9	5,3	5,5	8,1	5,2	5,2	5,1	5,0	5,0	7,4	4,5	4,6	6,4	4,8
E	Late Morning	Pack House	6	6,2	7,8	5,0	4,8	7,9	5,2	5,5	8,1	5,2	5,2	5,0	5,0	4,9	7,2	4,5	4,6	6,4	4,9
E	Late Morning	Pack House	6	6,2	7,5	5,0	4,8	7,8	5,2	5,5	8,0	5,2	5,2	5,0	5,0	4,9	7,0	4,5	4,6	6,4	5,0

Figure 4.98: Rise in temperature and temperature breaks recorded for the Late Morning trial for Farm E when pallets were kept in the holding room
Source: Captured by the author for the purpose of the study

F	Early Morning	Pack House	6	6,8	5,7	3,5	3,3	7,4	5,8	3,5	2,5	3,1
F	Early Morning	Pack House	6	7,0	5,8	3,9	3,4	7,8	6,7	3,6	2,5	3,3
F	Early Morning	Pack House	6	7,2	5,9	4,3	3,4	8,1	7,2	3,8	2,5	3,3
F	Early Morning	Pack House	6	6,9	6,0	4,2	3,5	7,7	7,4	3,8	2,5	3,4
F	Early Morning	Pack House	6	6,8	6,9	4,2	3,6	7,5	7,3	3,9	2,5	3,5
F	Early Morning	Pack House	6	6,6	6,6	4,0	3,6	7,1	7,3	3,8	2,5	3,5
F	Early Morning	Pack House	6	6,3	6,4	3,9	3,7	6,8	7,3	3,8	3,0	3,5
F	Early Morning	Pack House	6	5,6	4,7	3,8	3,9	5,9	6,9	3,8	3,0	3,5
F	Early Morning	Pack House	6	5,0	3,9	3,9	3,9	5,3	6,5	3,8	3,0	3,5
F	Early Morning	Pack House	6	4,7	3,5	3,8	3,9	5,1	6,0	3,8	2,5	3,5

Figure 4.99: Rise in temperature and a temperature spike recorded for the Early Morning trial for Farm F when the pallets were kept in the holding room
Source: Captured by the author for the purpose of the study

Figure 4.100: The cold room where pallets are held before packaging
Source: Captured by the author for the purpose of the study

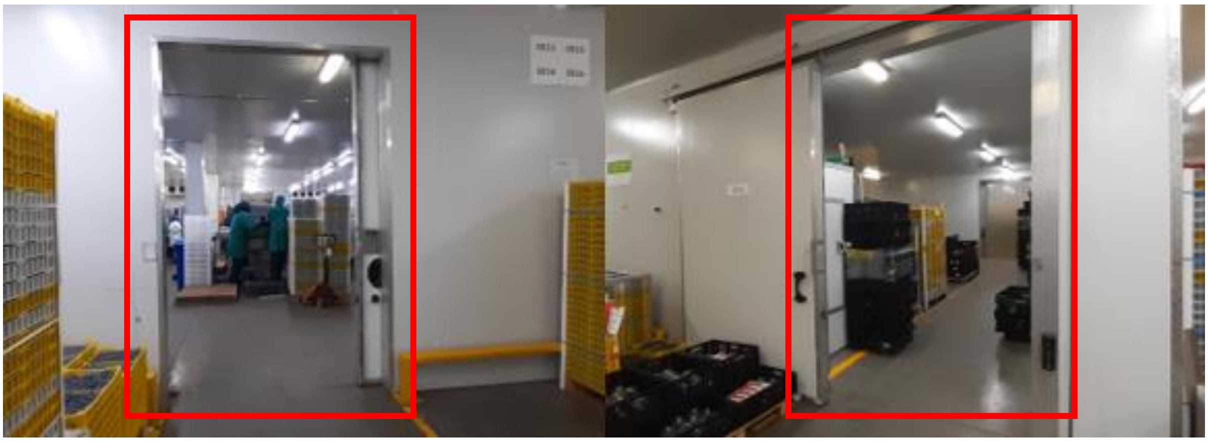


Figure 4.101: The doors that lead to the packing room (left) and the cold room (right) often stood open
Source: Captured by the author for the purpose of the study

Figure 4.102 shows that the space inside the packing room was quite limited. Inside the packing room, visibly warmer temperatures of 9.2ºC, 9.7ºC and 9.3ºC were recorded on three separate days. All three trials for Farms D-F in Gauteng recorded temperature spikes, while some recorded temperature breaks when the pallets entered the packing room. During packaging, a maximum temperature of 18.2ºC (**Figure 4.103**) and 13.7ºC (**Figure 4.104**) was recorded for the Afternoon trial for Farm D1 and Farm E, respectively. Furthermore, the pallets of Farm F entered the packing room on two separate occasions. During the first stint, only half of the iButtons® were removed, packed and transported to the forced cooler. The remaining crates, containing the other half of the iButtons®, were returned to the cold room and only transported to the forced cooler the next morning. When the remaining crates entered the packing room for the second time, a clear rise in temperature was once again observed in the data for Farm F (**Figure 4.105**).

Figure 4.102: Limited space available in the packing room
Source: Captured by the author for the purpose of the study

D1	Afternoon	Pack House		6	4,9	5,1	7,4	6,7	5,2	5,1	4,7	5,0	5,3	5,7	4,7	5,1	5,1	6,9	5,0	5,3	4,9	5,0
D1	Afternoon	Pack House		6	4,9	5,4	7,7	6,9	5,2	5,1	4,7	5,2	5,5	5,9	4,7	5,2	5,2	7,0	5,1	5,4	5,0	5,2
D1	Afternoon	Pack House		6	5,0	5,5	7,9	7,1	5,4	5,3	4,9	5,3	5,7	6,2	4,8	5,3	5,3	7,3	5,1	5,6	5,0	5,3
D1	Afternoon	Pack House		6	5,0	5,6	8,3	7,3	5,4	5,4	4,9	5,5	5,7	6,3	4,8	5,3	5,4	7,5	5,2	5,8	5,1	5,4
D1	Afternoon	Pack House		6	5,1	5,7	8,5	7,6	5,6	5,5	5,1	5,7	5,9	6,6	4,9	5,4	5,5	7,7	5,2	5,9	5,2	5,6
D1	Afternoon	Pack House		6	5,2	5,7	8,7	7,8	5,7	5,7	5,2	5,9	5,9	6,8	4,9	5,4	5,6	7,9	5,4	6,0	5,2	5,7
D1	Afternoon	Pack House		6	5,3	5,9	8,9	7,9	5,9	5,8	5,3	6,0	6,0	7,0	4,9	5,5	5,6	8,0	5,4	6,2	5,3	5,9
D1	Afternoon	Pack House		6	5,4	6,1	9,4	8,3	6,0	6,0	5,4	6,2	6,2	7,2	5,0	5,6	5,8	8,2	5,6	6,3	5,5	6,0
D1	Afternoon	Pack House		6	5,6	6,3	10,5	10,2	6,2	6,1	5,6	6,4	6,6	7,4	5,1	5,8	6,0	8,7	5,7	6,5	7,2	7,9
D1	Afternoon	Pack House		6	8,9	8,4	10,9	9,9	9,2	8,7	7,4	7,9	8,1	8,7	7,8	8,1	8,5	9,4	8,5	9,1	9,0	9,6
D1	Afternoon	Pack House		6	17,9	18,2	10,4	9,2	8,7	11,3	9,3	8,4	9,4	9,9	9,3	9,4	9,3	10,0	9,8	9,8	9,7	9,9
D1	Afternoon	Pack House		6	11,8	11,7	8,8	7,5	7,5	8,7	7,4	7,2	7,5	10,7	10,1	10,1	10,0	10,5	10,5	10,3	10,2	10,3
D1	Afternoon	Pack House		6	8,9	8,8	8,0	6,9	7,2	7,5	6,7	6,6	7,0	11,2	10,7	10,6	10,5	10,9	10,9	10,6	10,6	10,6
D1	Afternoon	Pack House		6	7,4	7,4	7,5	6,4	7,0	6,8	6,4	6,2	6,7	8,3	9,8	8,1	14,2	9,0	10,3	10,2	7,7	9,6
D1	Afternoon	Pack House		6	6,7	6,7	7,3	6,1	7,0	6,3	6,2	5,9	6,4	6,8	8,3	6,5	9,9	7,0	7,9	8,1	6,3	7,6
D1	Afternoon	Pack House		6	6,4	6,4	7,2	6,0	6,9	6,2	6,1	5,8	6,3	6,3	7,4	6,0	8,3	6,5	6,9	7,1	5,9	6,7
D1	Afternoon	Pack House		6	6,2	6,2	7,0	5,9	6,9	6,1	6,1	5,7	6,3	6,2	7,2	5,9	7,7	6,2	6,4	6,8	5,8	6,4

Figure 4.103: Rise in temperature and temperature spikes and breaks recorded for the Afternoon trial for Farm D1 when pallets were kept in the packing room
Source: Compiled by the author for the purpose of the study

E	Afternoon	Pack House	6	4,4	4,4	5,1	4,9	5,5	4,7	4,9	4,8	4,6	5,1	4,9	4,8	5,7	4,9	4,6	6,0	6,1
E	Afternoon	Pack House	6	4,5	4,4	6,7	6,7	7,3	6,8	6,7	7,4	6,8	6,9	6,9	7,0	7,2	7,0	6,6	6,0	6,1
E	Afternoon	Pack House	6	4,5	4,5	7,5	7,3	7,9	7,7	7,9	7,8	7,3	7,4	7,8	7,5	7,9	7,9	7,3	6,0	6,2
E	Afternoon	Pack House	6	4,6	4,6	8,0	7,7	8,2	8,2	8,7	8,4	7,6	7,9	8,3	7,9	8,2	8,7	7,7	6,2	6,3
E	Afternoon	Pack House	6	4,6	4,6	8,9	8,2	10,9	9,1	9,7	9,5	8,6	9,1	9,4	8,4	8,8	9,4	9,0	6,2	6,4
E	Afternoon	Pack House	6	4,6	4,6	7,9	7,1	10,1	8,2	9,6	8,9	8,8	9,4	9,5	8,8	9,1	9,7	9,2	6,2	6,5
E	Afternoon	Pack House	6	4,6	4,6	7,3	6,7	8,6	7,6	9,6	8,4	9,1	9,6	9,6	9,1	9,4	9,7	9,2	6,2	6,5
E	Afternoon	Pack House	6	5,4	5,4	7,0	6,6	7,7	7,3	9,6	7,7	9,1	9,7	9,6	9,3	9,5	9,7	9,3	6,2	6,5
E	Afternoon	Pack House	6	7,4	7,7	6,8	6,6	7,1	6,9	9,0	7,0	9,7	10,4	9,8	9,5	9,8	10,2	9,9	7,8	7,9
E	Afternoon	Pack House	6	8,7	9,1	6,7	6,5	6,8	6,6	7,3	6,7	9,7	13,4	12,2	11,2	9,8	9,8	13,7	9,0	8,9
E	Afternoon	Pack House	6	9,5	9,8	6,6	6,5	6,7	6,3	6,7	6,5	8,2	9,8	9,8	9,2	8,3	8,6	10,2	9,8	9,6
E	Afternoon	Pack House	6	10,0	10,3	6,6	6,5	6,6	6,1	6,3	6,5	7,6	7,9	8,2	8,2	7,3	7,9	8,7	10,3	10,1
E	Afternoon	Pack House	6	10,3	10,6	6,6	6,5	6,6	6,1	6,1	6,5	7,4	7,0	7,4	7,6	6,8	7,7	7,9	10,7	10,4
E	Afternoon	Pack House	6	10,7	10,9	6,6	6,5	6,6	6,1	6,1	6,5	7,3	6,6	6,8	7,4	6,6	7,6	7,6	11,0	10,7
E	Afternoon	Pack House	6	10,9	11,1	6,4	6,5	6,5	5,9	5,9	6,4	7,1	6,3	6,4	7,3	6,5	7,4	7,5	11,4	11,1
E	Afternoon	Pack House	6	9,8	10,5	6,4	6,5	6,5	5,9	5,9	6,4	7,1	6,2	6,4	7,2	6,4	7,4	7,4	11,7	9,9
E	Afternoon	Pack House	6	8,2	8,1	6,4	6,5	6,5	6,0	5,9	6,4	7,1	6,2	6,4	7,2	6,4	7,4	7,3	9,4	8,7
E	Afternoon	Pack House	6	6,9	6,4	6,4	6,5	6,5	5,9	5,8	6,4	7,1	6,2	6,1	7,2	6,4	7,4	7,3	7,4	7,5
E	Afternoon	Pack House	6	6,1	5,3	6,3	6,4	6,4	5,8	5,7	6,3	7,1	6,2	5,9	7,2	6,3	7,3	7,2	6,3	6,5
E	Afternoon	Pack House	6	5,6	5,0	6,3	6,4	6,4	5,8	5,7	6,3	7,1	6,2	6,0	7,1	6,3	7,2	7,2	5,8	6,0

Figure 4.104: Rise in temperature and temperature spikes and breaks recorded for the Afternoon trial of Farm E when in the packing room
Source: Compiled by the author for the purpose of the study

F	Early Morning	Pack House	6	4,8	4,1	4,5	4,5	4,5	4,6	4,4	4,1
F	Early Morning	Pack House	6	5,5	4,4	4,6	4,5	4,6	4,8	4,6	4,3
F	Early Morning	Pack House	6	7,3	6,5	7,1	6,5	5,9	6,8	6,8	6,9
F	Early Morning	Pack House	6	8,9	8,3	9,3	8,5	6,4	6,5	8,7	6,5
F	Early Morning	Pack House	6	8,3	7,8	9,8	9,0	6,3	6,4	8,6	6,0
F	Early Morning	Pack House	6	7,4	6,8	8,1	8,0	6,2	6,5	7,1	6,0
F	Early Morning	Pack House	6	6,9	6,4	7,4	7,0	6,3	6,5	6,6	6,0
F	Early Morning	Pack House	6	6,8	6,1	7,0	7,0	6,3	6,6	6,3	6,0

Figure 4.105: Rise in temperature and temperature spikes recorded for the Early Morning trial for Farm F when in the packing room for the second time
Source: Compiled by the author for the purpose of the study

Pallets were moved to a cold room after being strapped and labelled (**Figure 4.106**). Here each pallet was once again inspected. However, this inspection was carried out by an employee from the PPECB. If approved, the pallet was moved to the holding room to be weighed before the reefer truck arrived.

Figure 4.106: Completed pallets standing in a cold room before being moved to the holding room
Source: Captured by the author for the purpose of the study

4.9.2.6. Transportation to Forced Cooling

As discussed in section 4.7, with reference to Farm F, the researcher had to adapt as packing schedules at the packhouse which led to half of Farm F's blueberries being packed and transported to the forced cooling facility while the rest remained stationary in the packhouse. Therefore, the Transportation to Forced Cooling stage in Gauteng was recorded on two separate occasions. The pallets from Farms D1, E and half of Farm F's pallets, departed on the evening of 11 September. The other half of Farm F was packed and transported on the morning of 12 September. The Transportation to Forced Cooling stage for this pallet is discussed later. **Figure 4.107** shows pallets standing in the holding room while in the process of being loaded for transportation to the forced cooler on the evening of the 11th. During the loading of pallets, the door leading outside stood open, causing the heat from outside to enter the holding room (**Figure 4.108**). All the pallets loaded that evening recorded a fluctuation in temperature during the loading process. Farm E recorded temperature spikes for all three trials while the Late Morning trial also recorded a temperature break during the loading process (**Figure 4.109**). **Figure 4.110** shows the temperature spikes recorded for the Late Morning trial for Farm F.

Figure 4.107: Completed pallets standing in the holding room while being loaded for transportation to the forced cooler
Source: Captured by the author for the purpose of the study

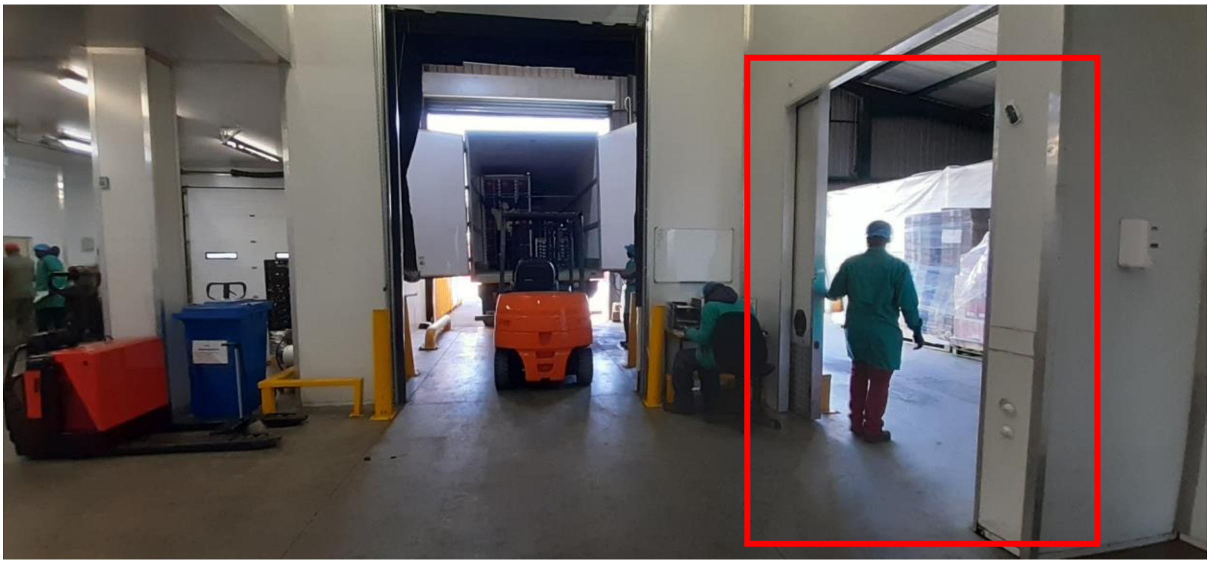


Figure 4.108: The door in the holding room not closed as protocol dictates
Source: Captured by the author for the purpose of the study

E	Late Morning	Pack House	6	6,9	7,3	7,7	7,4	6,8	6,7	6,7	6,6	7,1	6,2	6,2	6,2	5,9	5,7	5,9	6,1	6,6	6,3
E	Late Morning	Pack House	6	7,0	7,4	7,9	7,5	6,9	7,0	6,8	7,2	7,1	6,3	6,4	6,2	6,0	5,8	6,1	6,2	6,7	6,3
E	Late Morning	Pack House	6	7,0	7,5	8,0	7,5	6,9	7,2	6,8	7,5	7,2	6,4	6,5	6,4	6,1	5,9	6,2	6,3	6,8	6,5
E	Late Morning	Pack House	6	7,1	7,6	8,1	7,5	7,0	7,4	6,9	7,7	7,3	6,5	6,6	6,4	6,2	6,0	6,2	6,3	6,9	6,5
E	Late Morning	Pack House	6	7,1	7,6	8,2	7,6	7,0	7,5	6,9	7,8	7,3	6,5	6,6	6,4	6,2	6,0	6,3	6,3	6,9	6,6
E	Late Morning	Pack House	6	7,1	7,6	8,2	7,6	7,0	7,6	7,0	7,9	7,4	6,6	6,7	6,5	6,3	6,1	6,4	6,4	7,0	6,6
E	Late Morning	Transportation to Forced Cooler	6	7,1	7,6	8,2	7,7	7,0	7,6	7,0	8,0	7,4	6,6	6,7	6,6	6,3	6,2	6,4	6,4	7,1	6,7
E	Late Morning	Transportation to Forced Cooler	6	7,3	7,7	9,6	8,2	7,1	7,5	7,1	8,9	7,5	7,0	7,4	6,8	7,0	6,2	6,4	6,8	7,1	7,2
E	Late Morning	Transportation to Forced Cooler	6	7,2	7,4	10,3	8,5	6,9	7,2	7,1	9,2	7,8	7,5	8,2	6,4	7,2	6,2	6,1	6,6	6,9	7,5
E	Late Morning	Transportation to Forced Cooler	6	7,0	7,3	9,9	8,5	6,7	7,1	6,9	9,1	7,8	7,6	8,3	6,2	7,4	6,1	5,9	6,6	6,9	7,2
E	Late Morning	Transportation to Forced Cooler	6	7,0	7,2	9,7	8,5	6,3	7,0	6,9	8,9	7,8	7,5	8,2	6,2	7,4	6,0	5,9	6,6	6,7	7,0
E	Late Morning	Transportation to Forced Cooler	6	7,0	7,1	8,4	8,1	6,2	7,0	6,8	8,4	7,8	7,3	7,8	6,2	7,2	5,9	5,9	6,5	6,7	6,9
E	Late Morning	Transportation to Forced Cooler	6	6,9	7,0	7,1	7,5	5,9	7,0	6,7	7,5	7,4	6,9	7,0	6,2	6,8	5,8	5,9	6,4	6,6	6,8
E	Late Morning	Transportation to Forced Cooler	6	6,9	6,8	6,4	7,2	5,7	7,0	6,6	6,7	7,3	6,5	6,5	6,2	6,4	5,7	5,9	6,3	6,6	6,6
E	Late Morning	Transportation to Forced Cooler	6	6,9	6,8	6,8	7,3	5,8	7,0	6,5	6,5	7,2	6,3	6,4	6,2	6,2	5,7	6,0	6,3	6,4	6,6
E	Late Morning	Transportation to Forced Cooler	6	6,9	6,7	5,9	6,8	5,6	7,0	6,4	6,2	7,0	6,2	6,0	6,2	6,0	5,6	6,0	6,3	6,4	6,6
E	Late Morning	Transportation to Forced Cooler	6	6,9	6,7	5,2	6,4	5,3	7,0	6,4	5,7	6,8	5,8	5,6	6,2	5,7	5,5	6,0	6,1	6,4	6,5
E	Late Morning	Transportation to Forced Cooler	6	6,9	6,6	4,8	6,1	5,1	7,0	6,3	5,2	6,6	5,6	5,2	6,2	5,5	5,5	6,0	6,1	6,3	6,4

Figure 4.109: Temperature spikes and breaks recorded for the Late Morning trial for Farm E during the loading of pallets
Source: Compiled by the author for the purpose of the study

F	Late Morning	Pack House	6	5,9	6,2	6,1	7,1	6,5
F	Late Morning	Pack House	6	6,0	6,3	6,4	7,4	6,5
F	Late Morning	Pack House	6	6,1	6,3	6,5	7,5	6,5
F	Late Morning	Pack House	6	6,1	6,3	6,6	7,5	6,5
F	Late Morning	Pack House	6	6,3	6,4	6,7	7,6	6,5
F	Late Morning	Pack House	6	6,3	6,6	6,7	7,6	6,5
F	Late Morning	Transportation to Forced Cooler	6	6,4	6,8	6,9	8,3	7,5
F	Late Morning	Transportation to Forced Cooler	6	6,4	6,9	6,8	8,4	8,0
F	Late Morning	Transportation to Forced Cooler	6	6,3	7,2	6,6	7,1	7,5
F	Late Morning	Transportation to Forced Cooler	6	6,3	7,2	6,4	6,3	7,0
F	Late Morning	Transportation to Forced Cooler	6	6,1	6,9	6,3	5,5	7,0
F	Late Morning	Transportation to Forced Cooler	6	6,0	6,7	6,2	4,9	7,0
F	Late Morning	Transportation to Forced Cooler	6	5,9	6,3	6,1	4,1	6,5
F	Late Morning	Transportation to Forced Cooler	6	5,8	6,0	6,1	3,5	6,5

Figure 4.110: Temperature spikes recorded for the Late Morning trial for Farm F during the loading of pallets
Source: Captured by the author for the purpose of the study

Figure 4.111 shows the location where the pallets were offloaded on the evening of 11 September. Protocol was not followed as the pallets were not offloaded in a cold room (**Figure 4.111**). In addition, protocol dictates that pallets should be offloaded in a room that maintains a temperature of 6ºC. During offloading, a much higher temperature of 22.3ºC was recorded. After offloading a pallet, it was weighed and moved to a holding room. Protocol dictates that a temperature of 6ºC should be maintained while pallets are placed in a holding room. **Figure 4.112** shows that the holding room at the forced cooling facility does not function as a cold room. All three farms experienced temperature spikes during the above-mentioned procedure. **Figures 4.113** and **4.114** show the temperature spikes recorded for the Afternoon trial for Farm E and D1, respectively. After all the pallets were offloaded, they were moved from the holding room into a cold room. Forced cooling was applied the following morning.

Figure 4.111: Pallets were not offloaded in a cold room as protocol dictates
Source: Captured by the author for the purpose of the study

Figure 4.112: Pallets being moved from the holding room to the cold room
Source: Captured by the author for the purpose of the study

E	Afternoon	Transportation to Forced Cooler	6	4,5	4,3	5,4	5,8	2,1	3,3	6,2	4,0	5,9	5,9	4,2	6,9	6,6	6,1	1,5	4,4	4,3
E	Afternoon	Transportation to Forced Cooler	6	4,7	4,5	5,2	5,8	2,9	4,3	7,0	5,0	6,7	6,4	4,5	6,8	6,6	6,1	2,6	4,6	4,5
E	Afternoon	Transportation to Forced Cooler	6	4,9	4,7	5,3	5,8	5,7	5,4	7,6	6,7	7,5	7,2	5,4	6,8	6,5	6,3	5,1	4,7	4,7
E	Afternoon	Transportation to Forced Cooler	6	4,9	4,8	6,1	6,2	7,6	6,3	7,5	8,5	7,8	7,2	7,5	10,0	7,4	9,1	5,6	4,8	4,7
E	Afternoon	Transportation to Forced Cooler	6	4,0	4,4	6,2	6,1	7,5	7,1	7,6	8,2	7,9	7,3	8,6	10,6	8,0	9,3	5,9	4,2	4,4
E	Afternoon	Transportation to Forced Cooler	6	3,9	4,1	6,4	6,1	7,4	7,8	7,6	7,7	8,0	7,4	9,3	10,3	8,1	8,8	6,1	4,0	4,1
E	Afternoon	Transportation to Forced Cooler	6	4,3	4,1	6,5	6,1	7,3	8,1	7,6	7,5	8,0	7,6	9,8	10,0	8,2	8,8	6,2	4,1	4,2
E	Afternoon	Transportation to Forced Cooler	6	4,5	4,3	6,6	6,1	7,1	8,2	7,7	7,3	8,2	7,7	9,8	9,7	8,1	8,6	6,6	4,4	4,3
E	Afternoon	Transportation to Forced Cooler	6	4,7	4,5	6,2	5,9	5,4	6,9	6,1	6,5	5,3	6,2	6,6	7,1	6,2	7,6	6,2	4,5	4,5
E	Afternoon	Transportation to Forced Cooler	6	4,8	4,6	6,1	5,8	4,4	5,8	5,1	5,8	4,3	5,5	4,9	6,5	5,2	6,9	5,6	4,7	4,6

Figure 4.113: Temperature spikes recorded for the Afternoon trial for Farm E during the offloading of pallets
Source: Compiled by the author for the purpose of the study

D1	Afternoon	Transportation to Forced Cooler	6	6,0	6,2	5,2	5,3	6,9	5,6	5,4	4,7	5,4	6,0	3,9	5,7	5,5	3,7	5,3	2,2	6,0	5,7
D1	Afternoon	Transportation to Forced Cooler	6	6,0	6,2	5,0	5,2	6,9	5,6	5,6	5,6	5,3	5,9	4,2	5,8	5,4	4,3	5,4	2,0	6,0	6,0
D1	Afternoon	Transportation to Forced Cooler	6	6,1	6,2	5,0	5,2	7,0	6,0	6,1	6,6	5,3	5,9	6,1	5,8	5,4	4,7	5,6	2,3	6,0	6,4
D1	Afternoon	Transportation to Forced Cooler	6	7,2	6,8	5,5	5,4	7,2	7,0	6,6	8,3	5,7	6,3	6,8	5,9	5,6	5,2	6,2	4,4	6,0	7,0
D1	Afternoon	Transportation to Forced Cooler	6	7,8	6,9	5,9	5,7	7,2	7,9	6,6	7,9	5,9	6,5	6,5	6,1	6,2	5,4	6,6	5,8	6,0	7,7
D1	Afternoon	Transportation to Forced Cooler	6	8,3	6,9	6,2	5,9	7,2	8,5	6,6	7,3	6,1	6,6	6,2	6,1	6,9	5,5	6,5	7,0	6,1	8,2
D1	Afternoon	Transportation to Forced Cooler	6	8,5	7,0	6,4	6,0	7,2	8,8	6,4	6,9	6,2	6,6	6,1	6,1	7,3	5,5	6,4	7,5	6,1	8,6
D1	Afternoon	Transportation to Forced Cooler	6	8,6	7,1	6,7	6,2	7,3	8,9	6,4	6,6	6,4	6,6	6,0	6,1	7,4	5,7	6,3	7,8	6,1	8,8
D1	Afternoon	Transportation to Forced Cooler	6	7,3	6,7	6,0	5,5	7,3	7,5	6,3	6,5	5,9	6,6	5,6	6,1	7,1	5,5	6,2	7,1	6,1	7,7
D1	Afternoon	Transportation to Forced Cooler	6	6,1	6,3	5,7	5,1	7,3	6,9	6,3	6,3	5,5	6,5	4,8	6,1	6,6	5,4	6,1	6,1	6,1	6,4
D1	Afternoon	Transportation to Forced Cooler	6	5,6	6,1	5,5	4,9	7,2	6,6	6,2	6,1	5,3	6,5	4,3	6,1	6,3	5,3	6,1	5,6	6,1	5,9
D1	Afternoon	Transportation to Forced Cooler	6	5,2	5,9	5,3	4,8	7,2	6,4	6,1	6,0	5,2	6,5	3,9	6,1	6,2	5,3	6,2	5,3	6,1	5,6
D1	Afternoon	Transportation to Forced Cooler	6	5,0	5,7	5,2	4,6	7,2	6,3	6,0	5,9	5,0	6,5	3,5	6,1	6,1	5,2	6,2	5,3	6,1	5,3

Figure 4.114: Temperature spikes recorded for the Afternoon trial for Farm D1 during the offloading of pallets
Source: Compiled by the author for the purpose of the study

The morning of 12 September the final pallet from Farm F was packed, inspected, and transported to the forced cooler. No temperature spikes or breaks were recorded during the Transportation to Forced Cooling stage. **Figure 4.115** shows the loading bay and air-lock system used during the offloading of the pallet inside a cold room. In contrast to the previous day, protocol was followed. **Figure 4.116** shows the door linking the holding and cold rooms. The pallet was moved from the cold room, weighed, and then transported through the holding room to the forced cooling room, as shown in **Figure 4.117**. Protocol was not followed as the area where the pallet was weighed as well as the holding room where it was kept, did not maintain temperatures of 6ºC.

Figure 4.115: Pallets being offloaded in the cold room while making use of the loading bay and air-lock system
Source: Captured by the author for the purpose of the study

Figure 4.116: Cold room used to maintain pallet temperatures
Source: Captured by the author for the purpose of the study

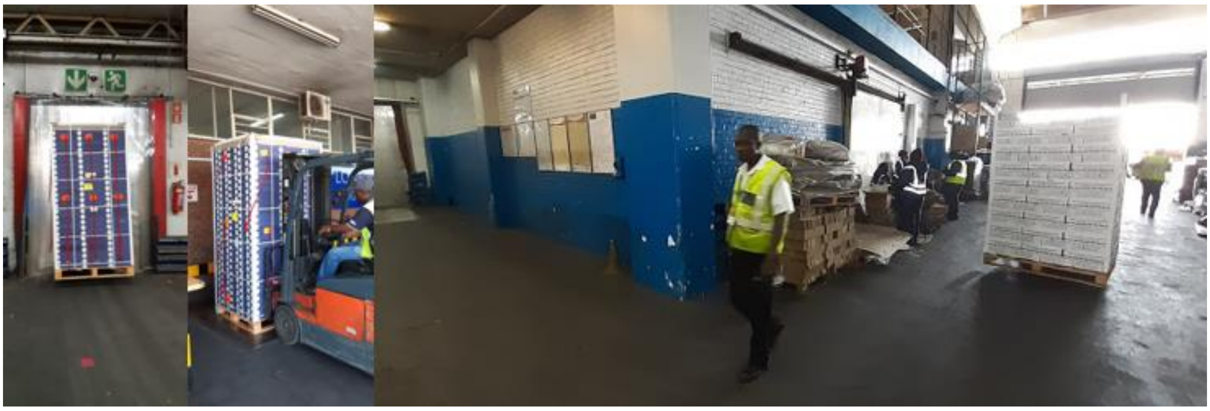


Figure 4.117: Pallet moved from the cold room, weighed, and subsequently transported through the holding room to the forced cooler
Source: Captured by the author for the purpose of the study

4.9.2.7. Forced Cooling

As discussed in section 4.7, Farm D1 recorded a total of 85 temperature spikes and 22 temperature breaks during the Forced Cooling stage. **Figure 4.118** displays some of the temperature spikes recorded for the Afternoon trial for Farm D1. After investigation, it was found that defrosting cycles could be the reason for most of these temperature spikes observed. The Early Morning and Afternoon trials recorded temperature breaks that lasted up to 1000 minutes (16.7 hours). During the Gauteng trials, the researcher was not able to remove the iButtons® and, therefore, required the assistance of an employee of Company X. The possibility exists that the assistant removed the iButtons® from the pallets and failed to mention this to the researcher. Therefore, causing the sharp rise in temperature observed and could be the reason for the long temperature breaks (**Figure 4.119**). In addition, **Figure 4.119** shows that a single iButton® for the Early Morning trial for Farm D1 recorded chilling injury breaks.

D1	Afternoon	Forced Cooling	0	0,2	0,0	0,2	0,1	0,5	0,8	-0,1	0,2	0,0	-0,1	-0,3	-0,1	0,5	-0,1	0,0	0,7	-0,1	-0,3
D1	Afternoon	Forced Cooling	0	0,4	0,1	0,2	0,2	0,5	0,8	-0,1	0,2	0,0	-0,1	-0,3	-0,1	0,6	-0,1	0,0	0,8	-0,1	-0,2
D1	Afternoon	Forced Cooling	0	0,6	0,1	0,2	0,2	0,5	0,9	-0,1	0,2	0,0	0,0	-0,2	-0,1	0,7	-0,1	0,0	0,9	-0,1	0,0
D1	Afternoon	Forced Cooling	0	0,8	0,2	0,2	0,2	0,5	1,0	-0,1	0,2	0,0	0,0	-0,2	-0,1	0,7	-0,1	0,0	1,0	-0,1	0,2
D1	Afternoon	Forced Cooling	0	1,0	0,3	0,2	0,2	0,5	1,2	-0,1	0,2	0,0	0,0	-0,2	-0,1	0,8	-0,1	0,0	1,2	-0,1	0,5
D1	Afternoon	Forced Cooling	0	1,2	0,3	0,2	0,2	0,5	1,2	-0,1	0,2	0,0	0,0	-0,2	-0,1	0,9	-0,1	0,0	1,3	-0,1	0,7
D1	Afternoon	Forced Cooling	0	2,7	1,9	0,7	1,9	1,0	1,3	0,6	1,3	1,1	1,1	1,2	0,9	0,9	0,3	0,7	1,4	-0,1	2,2
D1	Afternoon	Forced Cooling	0	3,1	2,9	1,3	2,5	2,0	1,3	1,7	2,1	2,2	2,5	2,1	1,7	1,0	1,1	1,7	1,4	0,1	2,8
D1	Afternoon	Forced Cooling	0	1,7	1,6	1,0	1,4	1,4	1,2	1,1	1,2	1,4	1,4	0,9	1,0	0,8	0,8	1,1	1,1	0,1	1,3
D1	Afternoon	Forced Cooling	0	0,8	0,8	0,7	0,7	1,0	0,9	0,6	0,7	0,8	0,7	0,2	0,5	0,5	0,4	0,5	0,8	0,1	0,3
D1	Afternoon	Forced Cooling	0	0,3	0,3	0,5	0,4	0,7	0,8	0,2	0,4	0,5	0,3	-0,1	0,2	0,4	0,1	0,2	0,6	0,0	-0,2
D1	Afternoon	Forced Cooling	0	0,1	0,0	0,4	0,1	0,5	0,7	0,0	0,2	0,3	0,0	-0,4	0,0	0,2	0,0	0,0	0,4	-0,1	-0,5
D1	Afternoon	Forced Cooling	0	-0,2	-0,2	0,2	0,0	0,3	0,6	-0,1	0,0	0,1	-0,2	-0,6	-0,2	0,2	-0,1	-0,2	0,4	-0,1	-0,7
D1	Afternoon	Forced Cooling	0	-0,3	-0,3	0,1	-0,2	0,3	0,5	-0,2	-0,1	0,0	-0,3	-0,7	-0,3	0,1	-0,2	-0,3	0,2	-0,1	-0,9
D1	Afternoon	Forced Cooling	0	0,2	0,2	0,2	0,2	0,5	0,6	0,0	0,2	0,3	0,1	-0,2	0,0	0,2	0,0	0,0	0,4	-0,1	-0,3
D1	Afternoon	Forced Cooling	0	-0,2	-0,3	0,1	-0,2	0,3	0,5	-0,2	-0,1	0,0	-0,3	-0,6	-0,3	0,1	-0,2	-0,3	0,2	-0,1	-0,8

Figure 4.118: Temperature spikes recorded for the Afternoon section for Farm D1 during the Forced Cooling stage
Source: Compiled by the author for the purpose of the study

D1	Early Morning	Forced Cooling	0	0,9	0,5	0,2	1,2	0,8	0,3	0,7	0,6	0,6	0,4	1,2	-2,0	-0,1	0,0	1,1	-0,5
D1	Early Morning	Forced Cooling	0	0,9	0,5	0,2	1,2	0,8	0,3	0,7	0,6	0,6	0,5	1,3	-2,0	-0,1	0,1	1,1	-0,5
D1	Early Morning	Forced Cooling	0	0,9	0,5	0,2	1,3	0,8	0,3	0,7	0,6	0,6	0,5	1,4	-2,0	0,0	0,1	1,1	-0,5
D1	Early Morning	Forced Cooling	0	0,9	0,5	0,2	1,4	0,8	0,3	0,7	0,6	0,6	0,5	1,4	-2,0	0,2	0,1	1,1	-0,5
D1	Early Morning	Forced Cooling	0	0,9	0,5	0,2	1,4	0,8	0,3	0,7	0,7	0,6	0,6	2,5	-2,0	1,2	0,2	1,2	-0,5
D1	Early Morning	Forced Cooling	0	0,9	0,5	0,2	1,5	0,9	0,3	0,7	0,7	0,6	0,8	3,2	-1,9	1,6	0,3	1,3	-0,4
D1	Early Morning	Forced Cooling	0	1,0	0,6	0,2	2,1	1,0	0,4	0,7	0,8	4,4	0,9	3,7	-1,9	6,4	0,4	1,3	3,5
D1	Early Morning	Forced Cooling	0	1,0	0,7	0,3	2,1	1,1	0,5	0,7	0,9	10,3	1,0	3,2	6,3	10,7	0,6	1,4	9,5
D1	Early Morning	Forced Cooling	0	1,1	0,7	0,3	1,9	1,0	0,5	0,7	1,0	10,3	1,1	3,0	7,8	11,1	0,6	1,4	9,9
D1	Early Morning	Forced Cooling	0	1,1	0,7	0,4	1,7	1,0	0,5	0,8	1,0	10,9	1,2	2,9	8,8	12,1	0,8	1,4	11,0
D1	Early Morning	Forced Cooling	0	1,1	0,7	0,4	1,6	1,0	0,5	0,8	1,0	14,3	5,3	6,5	10,1	13,7	5,5	5,3	11,6
D1	Early Morning	Forced Cooling	0									16,4	10,8	10,2	11,2	14,4	11,4	11,6	12,0
D1	Early Morning	Forced Cooling	0									17,6	12,7	12,5	11,7	14,9	14,2	15,4	12,5
D1	Early Morning	Forced Cooling	0									18,7	16,8	16,9	16,6	19,3	17,8	18,3	15,3
D1	Early Morning	Forced Cooling	0									20,4	17,8	20,1	17,7	20,8	19,1	19,0	16,5
D1	Early Morning	Forced Cooling	0									21,1	18,6	20,6	18,0	21,0	19,6	19,3	17,3
D1	Early Morning	Forced Cooling	0									21,3	19,1	20,7	18,2	21,0	19,8	19,6	17,7
D1	Early Morning	Forced Cooling	0									21,4	19,4	20,8	18,4	21,0	20,0	19,8	18,0

Figure 4.119: Temperature spikes, breaks and chilling injury breaks recorded for the Early Morning trial for Farm D1 during the Forced Cooling stage
Source: Compiled by the author for the purpose of the study

As discussed in section 4.7, no chilling injury spikes, or breaks were recorded for Farm E. However, Farm E did record a total of 81 temperature spikes and five temperature breaks. A single iButton® recorded all three temperature breaks observed for the Late Morning trial for Farm E. **Figure 4.120** shows some of the temperature spikes recorded for the Late Morning trial for Farm E during the Forced Cooling stage.

E	Late Morning	Forced Cooling	0	0,0	0,4	0,1	0,9	0,9	0,2	0,0	1,0	0,0	1,5	1,3	-0,1	0,5	-0,2	0,1	-0,2	0,3	0,3
E	Late Morning	Forced Cooling	0	0,1	0,4	0,1	0,9	0,9	0,4	0,0	1,1	0,0	1,6	1,3	-0,1	0,5	-0,2	0,2	-0,2	0,3	0,3
E	Late Morning	Forced Cooling	0	0,1	0,5	0,1	0,9	0,9	0,6	0,0	1,1	0,0	1,6	1,3	-0,1	0,5	-0,1	0,2	-0,2	0,3	0,3
E	Late Morning	Forced Cooling	0	0,3	0,5	0,2	1,0	0,9	0,8	0,0	1,1	0,0	1,6	1,4	0,0	0,6	-0,1	0,2	-0,2	0,3	0,3
E	Late Morning	Forced Cooling	0	0,3	0,5	0,2	1,0	1,0	0,9	0,0	1,2	0,0	1,6	1,4	0,0	0,6	0,0	0,3	-0,1	0,3	0,4
E	Late Morning	Forced Cooling	0	0,4	0,5	0,3	1,0	1,0	1,1	0,0	1,3	0,0	1,6	1,4	0,0	0,6	0,0	0,3	-0,1	0,3	0,4
E	Late Morning	Forced Cooling	0	2,6	1,0	1,0	1,1	1,0	3,0	1,3	1,3	2,9	1,6	1,4	2,2	0,7	0,8	0,9	1,9	1,6	0,4
E	Late Morning	Forced Cooling	0	3,0	2,0	2,0	1,4	1,1	3,1	2,1	1,3	2,4	1,7	1,5	2,4	1,4	1,8	1,7	2,1	2,5	1,1
E	Late Morning	Forced Cooling	0	1,3	1,3	1,3	1,3	1,2	1,5	1,1	1,2	1,0	1,7	1,5	1,0	1,0	1,1	1,2	0,9	1,5	0,9
E	Late Morning	Forced Cooling	0	0,5	0,8	0,8	1,1	1,1	0,6	0,5	1,1	0,4	1,6	1,4	0,2	0,6	0,5	0,6	0,2	0,8	0,6
E	Late Morning	Forced Cooling	0	0,1	0,4	0,4	1,1	1,0	0,1	0,2	1,1	0,0	1,6	1,3	-0,2	0,3	0,0	0,2	-0,2	0,5	0,3
E	Late Morning	Forced Cooling	0	-0,2	0,2	0,1	1,0	0,9	-0,2	0,0	1,0	-0,2	1,6	1,2	-0,4	0,1	-0,2	0,0	-0,4	0,3	0,2

Figure 4.120: Temperature spikes recorded for the Late Morning trial for Farm E during the Forced Cooling stage
Source: Compiled by the author for the purpose of the study

No chilling injury spikes, or breaks were recorded for Farm F as discussed in section 4.7. However, Farm F did record a total of 49 temperature spikes and eight temperature breaks. Farm F's Afternoon trial was the only trial where temperature breaks were recorded on more than one iButton®. All three temperature breaks recorded for the Afternoon 2 trial were recorded on a single iButton®. The longest temperature break recorded for the Afternoon trial for Farm F, lasted a total of 485 minutes (8 hours). All three trials for Farm F had iButtons® that never reached protocol temperature during the Forced Cooling stage, as discussed in section 4.8. Out of the 13 iButtons® that never reached protocol temperature, ten iButtons® were placed in the pallet that was packed on the morning of 12 September. The reason for this could be that the pallet did not stand in the holding cold room for long enough before being transported to the forced cooling facility. **Figure 4.121** shows how pallets were stacked against each other before forced cooling commenced.

Figure 4.121: Pallets stacked against each other before forced cooling commenced
Source: Captured by the author for the purpose of the study

4.10. Temperature Profile for Various Geographical Locations

As mentioned in Chapter 2 under section 2.9, various factors need to be taken into account when investigating the effect geographical locations have on the quality of fruit. One of the main factors that could influence fruit quality is the climatic conditions experienced on each farm, especially during harvest. Groenewald (2020:26) states that in an interview with a farm representative it was mentioned that the temperature on farms located 500 metres from each other can differ between four and seven degrees Celsius. In the current study, the researcher compared the maximum ambient temperatures recorded by the iButtons® with that of the maximum daily temperatures recorded by the South African Weather Service (SAWS). This comparison helped the researcher gain a better understanding of how the temperatures experienced by the blueberries were influenced by the climatic conditions during harvest. It is important to note that the temperatures recorded by the SAWS were not recorded on the farms itself but instead are temperatures recorded in locations closest to the farms. In the Western Cape, the SAWS temperatures were recorded between 10 and 45km from where the actual location's trials were conducted. Whereas in Gauteng, the SAWS temperatures were recorded between 15 and 45km from where the actual location's trials were conducted. Although, the temperatures were recorded close to the actual location, it should be noted that the accuracy of the temperatures can by slightly different to the actual temperature experienced. In addition, it is important to note that the temperature readings provided by the SAWS are recorded in the shade, while the temperatures recorded by the iButtons® were often in direct sunlight. This can have a significant impact on the temperatures recorded.

4.10.1. Western Cape

Table 4.22 provides a summarised comparison between the three farms on which trials were conducted in the Western Cape. The geographical location of these farms are spread out over the Wolseley, Wellington, and Robertson districts, and are referred to as Farms A, B and C. The farms are approximately (Farm A – 105km, Farm B – 120km and Farm C – 45km) away from Packhouse 1. This packhouse also functions as a cold store and is situated in the Robertson district. The Western Cape trials were conducted between 30 September 2019 and 15 November 2019. Farms A and B followed standard logistical processes, as discussed in section 2.7 and illustrated in **Figure 2.4**. In contrast, Farm C deviated from the standard logistical processes followed, by bypassing the Packhouse stage. In addition, Farm C made use of field packing by harvesting in lugs that are much larger than the standard one-litre buckets used on Farms A and B. All three farms planted their blueberries beneath shaded netting.

4.10.1.1. Conditions on the day of the trials (Farm A)

On the day of the trials on Farm A, the weather forecast was partly sunny. The Early Morning trial was conducted between 09:19 and 11:49, with the iButtons® recording a minimum and maximum harvesting temperature of 18.1ºC and 30.2ºC (09:54), respectively. While an average harvesting temperature of 21ºC was recorded for the same trial. The Late Morning trial was conducted between 10:44 and 11:49, with the iButtons® recording a minimum and maximum harvesting temperature of 20.8ºC and 41ºC (11:04), respectively. This trial displayed the highest recorded harvesting temperature out of the trials conducted on Farm A. The average harvesting temperature for the Late Morning trial was recorded at 25ºC. The Afternoon trial was conducted between 13:59 and 15:19, with the iButtons® recording a minimum and maximum harvesting temperature of 23.8ºC and 37.4ºC (14:14), respectively. The Afternoon trial recorded the highest average harvesting temperature of 26ºC of all the trials conducted on Farm A.

4.10.1.2. Conditions on the day of the trials (Farm B)

On the day of the trials on Farm B, the weather forecast was sunny. The Early Morning trial was conducted between 08:14 and 09:59, with the iButtons® recording a minimum and maximum harvesting temperature of 21.7ºC and 35.6ºC (08:59), respectively. An average harvesting temperature of 27.6ºC was recorded for the same trial. The Late Morning trial was conducted between 10:59 and 12:39, with the iButtons® recording a minimum and maximum harvesting temperature of 24.1ºC and 51.1ºC (11:39), respectively. It should be highlighted that this trial showcased not only the highest recorded harvesting temperature out of all the trials conducted on Farm B, but also the highest recorded harvesting temperature out of all the Western Cape farms. In addition, the Late Morning trial had the highest average harvesting temperature of 34.8ºC recorded during the trials conducted on Farm B. The Afternoon trial was conducted between 13:49 and 16:29 with the iButtons® recording a minimum and maximum harvesting temperature of 19ºC and 49.5ºC (14:04), respectively. The average harvesting temperature recorded for the Afternoon trial was 32.8ºC.

4.10.1.3. Conditions on the day of the trials (Farm C)

On the day of the trials on Farm C, the weather forecast was rainy with sun. The Early Morning trial was conducted between 10:19 and 12:54, with the iButtons® recording a minimum harvesting temperature of 21ºC. During harvest, at 10:45, it started raining for a few minutes. After which, at 10:53, pickers were instructed to continue picking. A maximum harvesting temperature of 28.9ºC was recorded at 10:34, a few minutes before the rain started. The average harvesting temperature for the Early Morning trial was recorded at 23.6ºC. Both these recordings were the highest recordings for the trials conducted on Farm C. The Late Morning trial was conducted between 13:34 and 16:34, with the iButtons® recording a minimum and maximum harvesting temperature of 20.6ºC and 24.2ºC (15:09), respectively. The average harvesting temperature recorded for the same trial was 22.5ºC. The Afternoon trial was conducted between 14:39 and 16:34 with the iButtons® recording a minimum and maximum harvesting temperature of 21.1ºC and 24.1ºC (15:09), respectively. The average harvesting temperature recorded for the Afternoon trial was 22.3ºC. As mentioned in Chapter 4 under the section, Average time spent per stage, the Harvest and Transportation stage ends, and the Pre-Cooling stage begins when a finished pallet was positioned against the forced cooling machine and the machine was turned on for pre-cooling to commence. This made sense as most of the farms had the same facilities regarding pre-cooling. However, for Farm C there was no forced cooling machine, therefore, the stage ended as soon as the pallets were moved into the cold room. The late Morning trials pallets and the Afternoon trials pallets moved into the cold room at the same time, which is the reason why the two stages ended at the same time.

Table 4.22: Overview of the three farms that trials were conducted on in the Western Cape

Western Cape	Farm A	Farm B	Farm C
Area located in	Wolseley	Wellington	Robertson
Month of trials	30 September 2019 to 4 October 2019	4 November 2019 to 7 November 2019	13 November 2019 to 15 November 2019
Logistical process used	Standard	Standard	Deviates from standard process – bypasses Packhouse stage
Farming style	Shaded Netting	Shaded Netting	Shaded Netting
Handling methods	One-litre buckets	One-litre buckets	Lugs
Conditions on day of trial			
Time of trials • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	09:19 – 11:49 10:44 – 11:49 13:59 – 15:19	08:14 – 09:59 10:59 – 12:39 13:49 – 16:29	10:19 – 12:54 13:34 – 16:34 14:39 – 16:34
Maximum harvesting temperatures • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 30.2ºC LM: 41ºC A: 37.4ºC	EM: 35.6ºC LM: 51.1ºC A: 49.5ºC	EM: 28.9ºC LM: 24.2ºC A: 24.1ºC

Time maximum harvesting temperatures recorded • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 09:54 LM: 11:04 A: 14:14	EM: 08:59 LM: 11:39 A: 14:04	EM: 10:34 LM: 15:09 A: 15:09
Minimum harvesting temperatures • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 18.1ºC LM: 20.8ºC A: 23.8ºC	EM: 21.7ºC LM: 24.1ºC A: 19ºC	EM: 21ºC LM: 20.6ºC A: 21.1ºC
Average harvesting temperatures • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 21ºC LM: 25ºC A: 26ºC	EM: 27.6ºC LM: 34.8ºC A: 32.8ºC	EM: 23.6ºC LM: 22.5ºC A: 22.3ºC

Source: Compiled by the author for the purpose of the study

4.10.1.4. iButtons® vs SAWS

Table 4.23 compares the maximum harvesting temperatures recorded by the iButtons® to the maximum harvesting temperatures recorded by the SAWS, on each farm in the Western Cape. The time at which the maximum harvesting temperature for both the iButtons® and SAWS were recorded, is also indicated. In addition, **Table 4.23** displays the temperature recorded by the SAWS at the same time at which the iButtons® recorded its maximum harvesting temperatures.

For Farm A, at 11:04, iButtons® recorded a maximum harvesting temperature of 41ºC, while the SAWS recorded a temperature of 16.5ºC. The SAWS recorded a maximum harvesting temperature of only 19.8ºC (15:34) for the day. The maximum harvesting temperature recorded by the iButtons® was 21.2ºC warmer than the maximum harvesting temperature recorded by the SAWS, for Farm A. At 11:39, the iButtons® on Farm B recorded a maximum harvesting temperature of 51.1ºC, while the SAWS recorded a temperature of 30.4ºC. The SAWS recorded a maximum harvesting temperature of 34.7ºC (13:47) for Farm B. Therefore, the maximum temperature experienced by the blueberries was 16.4ºC warmer than the maximum temperature recorded by the SAWS. Lastly, for Farm C, at 10:34, the iButtons® recorded a maximum harvesting temperature of 28.9ºC, while the SAWS recorded a temperature of 19.9ºC. The SAWS recorded a maximum harvesting temperature of 22.8ºC at 14:38. For Farm C, the difference between the maximum harvesting temperature recorded by the iButtons® and SAWS respectively, were the smallest with the former being 6.1ºC warmer.

Consultation with an industry expert, identified that the respiration of the fruit combined with the fact that the temperature measured by the iButtons® was in direct sunlight could be one of the reasons why significant differences in temperature were observed between the temperatures recorded by the iButtons® and the SAWS respectively. In addition, the researcher highlighted earlier that on certain farms in the Western Cape, steel tables were used, which generated a lot of heat. Crates and one-litre buckets were left in the sun and could also have contributed to the higher temperatures recorded by the iButtons®. Lastly, it is important to mention, that whilst the temperatures recorded by the iButtons® were often in direct sunlight, the temperature readings provided by the SAWS were recorded in the shade and the temperature readings by the SAWS were not on the farms themselves.

Table 4.23: Comparison between the maximum temperatures recorded and the time at which these temperatures were recorded for the farms in the Western Cape

Western Cape		Max Temp	Time Max Temp
Farm A	• SAWS • iButtons® (SAWS Temp)	19.8ºC 41ºC (16.5ºC)	15:34 11:04
Farm B	• SAWS • iButtons® (SAWS Temp)	34.7ºC 51.1ºC (30.4ºC)	13:47 11:39
Farm C	• SAWS • iButtons® (SAWS Temp)	22.8ºC 28.9ºC (19.9ºC)	14:38 10:34

Source: Compiled by the author for the purpose of the study

4.10.2. Gauteng

Table 4.24 provides a summarised comparison between the three farms on which trials were conducted in Gauteng. The geographical location of these farms are spread out. Farm D is situated close to Magaliesburg, Farm E is situated in the Moddersspruit district and Farm F is situated in the Mooinooi district. All three farms are roughly 140km from Packhouse 2, where after finished pallets need to be transported to Cold Store 2 to receive forced cooling. Cold Store 2 is 5.6km from Packhouse 2. The Gauteng trials were conducted between 10 and 14 September 2019. Due to an error by the researcher, trials had to be rerun on Farm D. The rerun was conducted on 13 and 14 November 2019. All three farms followed standard logistical processes, as discussed in section 2.7 and illustrated in **Figure 2.4**. Furthermore, Farms D2 and E made use of the conventional one-litre buckets during harvest. In contrast, Farm F uses buckets smaller than the one-litre buckets. All three farms planted their blueberries beneath shaded netting.

4.10.2.1. Conditions on the day of the trials (Farm D2)

On the day of the trials on Farm D2, the weather forecast was sunny. The Early Morning trial was conducted between 09:19 and 10:29, with the iButtons® recording a minimum and maximum harvesting temperature of 22.4ºC and 30.4ºC (09:24), respectively. While an average harvesting temperature of 26ºC was recorded for the same trial. The Late Morning trial was conducted between 10:24 and 11:29, with the iButtons® recording a minimum and maximum harvesting temperature of 24.7ºC and 37ºC (10:29), respectively. The average harvesting temperature for the Late Morning trial was recorded at 28.7ºC. The Afternoon trial was conducted between 13:24 and 14:19, with the iButtons® recording a minimum and maximum harvesting temperature of 28.3ºC and 39.1ºC (13:34), respectively. This trial displayed the highest recorded harvesting temperature as well as the highest average harvesting temperature of 31.4ºC out of all the trials conducted on Farm D2. In addition, the average harvesting temperature recorded for Farm D, was the highest recorded average harvesting temperature out of all the farms in Gauteng.

4.10.2.2. Conditions on the day of the trials (Farm E)

On the day of the trials on Farm E, the weather forecast was sunny. The Early Morning trial was conducted between 08:54 and 18:34, with the iButtons® recording a minimum and maximum harvesting temperature of 10.6ºC and 30.8ºC (09:54), respectively. While an average harvesting temperature of 21.5ºC was recorded for the same trial. The Late Morning trial was conducted between 13:29 and 18:34, with the iButtons® recording a minimum and maximum harvesting temperature of 26.6ºC and 40.9ºC (13:59), respectively. The average harvesting temperature for the Late Morning trial was recorded at 30.7ºC. This trial displayed the highest recorded harvesting temperature as well as the highest average harvesting temperature for Farm E. The Afternoon trial was conducted between 14:54 and 18:34, with the iButtons® recording a minimum and maximum harvesting temperature of 26.8ºC and 35.6ºC (15:29), respectively. An average harvesting temperature of 30ºC was recorded for the same trial. As mentioned in Chapter 4 under the section 4.6, the Harvest and Transportation stage ends, and the Pre-Cooling stage begins when a finished pallet was positioned against the forced cooling machine and the machine was turned on for pre-cooling to commence. For the trials conducted on Farm E, it is noteworthy to mention that all the trials ended at 18:34. The reason for this was because the fruit of all three trails were moved into the pre-cooling room at the same time.

4.10.2.3. Conditions on the day of the trials (Farm F)

On the day of the trials on Farm F, the weather forecast was sunny. The Early Morning trial was conducted between 07:39 and 08:54, with the iButtons® recording a minimum and maximum harvesting temperature of 17.5ºC and 27.5ºC (08:14), respectively. While an average harvesting temperature of 21.1ºC was recorded for the same trial. The Late Morning trial was conducted between 09:09 and 12:34, with the iButtons® recording a minimum and maximum harvesting temperature of 9ºC and 32.2ºC (09:39), respectively. The average harvesting temperature for the Late Morning trial was recorded at 22.8ºC. The Afternoon trial was conducted between 13:04 and 14:19, with the iButtons® recording a minimum and maximum harvesting temperature of 26.8ºC and 38.6ºC (13:24), respectively. This trial displayed the highest recorded harvesting temperature as well as the highest average harvesting temperature of 28.5ºC for Farm F.

Table 4.24: Overview of the three farms that trials were conducted on in Gauteng

Gauteng	Farm D2	Farm E	Farm F
Area located in	Magaliesburg	Modderspruit	Mooinooi
Month of trials	13 November 2019 to 14 November 2019	10 September 2019 to 13 September 2019	10 September 2019 to 14 September 2019

Logistical process used	Standard	Standard	Standard
Farming style	Shaded Netting	Shaded Netting	Shaded Netting
Handling methods	One-litre buckets	One-litre buckets	Used buckets smaller than the conventional one-litre buckets
Conditions on day of trial			
Time of trials • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	09:19 – 10:29 10:24 – 11:29 13:24 – 14:19	08:54 – 18:34 13:29 – 18:34 14:54 – 18:34	07:39 – 08:54 09:09 – 12:34 13:04 – 14:19
Maximum harvesting temperatures • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 30.4ºC LM: 37ºC A: 39.1ºC	EM: 30.8ºC LM: 40.9ºC A: 35.6ºC	EM: 27.5ºC LM: 32.2ºC A: 38.6ºC
Time maximum harvesting temperatures recorded • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 09:54 LM: 10:29 A: 13:34	EM: 09:54 LM: 13:59 A: 15:29	EM: 08:14 LM: 09:39 A: 13:24
Minimum harvesting temperatures • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 22.4ºC LM: 24.7ºC A: 28.3ºC	EM: 10.6ºC LM: 266ºC A: 26.8ºC	EM: 17.5ºC LM: 9ºC A: 26.8ºC

Average harvesting temperatures • Early Morning (EM) • Late Morning (LM) • Afternoon (A)	EM: 26ºC LM: 28.7ºC A: 31.4ºC	EM: 21.5ºC LM: 30.7ºC A: 30ºC	EM: 21.1ºC LM: 22.8ºC A: 28.5ºC

Source: Compiled by the author for the purpose of the study

4.10.2.4. iButtons® vs SAWS

Table 4.25 compares the maximum harvesting temperatures recorded by the iButtons® to the maximum harvesting temperatures recorded by the SAWS on each farm in Gauteng. The time at which the maximum harvesting temperature for both the iButtons® and SAWS were recorded, is also indicated. In addition, **Table 4.25** displays the temperature recorded by the SAWS at the same time at which the iButtons® recorded its maximum harvesting temperatures.

For Farm D2, iButtons® recorded a maximum harvesting temperature of 39.1ºC at 13:34, while the SAWS recorded a temperature of 25.1ºC. The SAWS recorded a maximum harvesting temperature of only 26.4ºC (15:10) for the day. The maximum harvesting temperature recorded by the iButtons® was 12.7ºC warmer than the maximum harvesting temperature recorded by the SAWS, for Farm D2. At 13:59, the iButtons® on Farm E recorded a maximum harvesting temperature of 40.9ºC, while the SAWS recorded a temperature of 29.6ºC. The SAWS recorded a maximum harvesting temperature of 30.6ºC (15:36) for Farm E. In addition, the maximum temperature experienced by the blueberries was 10.3ºC warmer than the maximum temperature recorded by the SAWS. Lastly, for Farm F, at 13:24, the iButtons® recorded a maximum harvesting temperature of 38.6ºC, while the SAWS recorded a temperature of 29.2ºC. The SAWS recorded a maximum harvesting temperature of 30.6ºC at 15:36. For Farm F, the difference between the maximum harvesting temperature recorded by the iButtons® and the SAWS, respectively, were the smallest with the former being 8ºC warmer.

Similar to the Western Cape, the temperatures recorded by the SAWS and the temperatures of the trials conducted in Gauteng generally did not correspond. After consulting an industry expert and examining the conditions, the same reasons given for this discrepancy, which was mentioned in section 4.10.1.4, also apply for Gauteng.

Table 4.25: Comparison between the maximum temperatures recorded and the time at which these temperatures were recorded for the farms in Gauteng

Gauteng		Max Temp	Time Max Temp
Farm D2	• SAWS • iButtons® (SAWS Temp)	26.4ºC 39.1ºC (25.1ºC)	15:10 13:34
Farm E	• SAWS • iButtons® (SAWS Temp)	30.6ºC 40.9ºC (29.6ºC)	15:36 13:59
Farm F	• SAWS • iButtons® (SAWS Temp)	30.6ºC 38.6ºC (29.2ºC)	15:36 13:24

Source: Compiled by the author for the purpose of the study

4.11. Quality Control

As mentioned in the Quality Control section in Chapter 2, Faria-Fernandes *et al*., (2009) defines quality control as "the function which aims to measure and improve the production and marketing processes, as well as the product and information flow, in order to provide products according to specification". This section aims to collect product information from QC reports, as recorded by the end customer upon arrival at the destination. The QC reports for each pallet representing either the Western Cape or Gauteng farms, where trials were conducted, are examined and discussed. In addition, the information is used to find a link, if any, between the quality of the fruit and temperature breaks. Furthermore, this section strives to identify whether protocols were followed, as protocols dictate that temperature should be maintained at 0ºC during transit.

4.11.1. Western Cape

4.11.1.1. Farm A

A quality control report was retrieved for the blueberries harvested on Farm A. Unfortunately, data for only one out of the two pallets could be retrieved. The blueberry variety harvested for pallet 760091600208030295 was EB8-42 packed in 3.5kg boxes, as shown in **Figure 4.122**. Upon arrival at the destination, the average temperature recorded for this pallet was 3.57ºC. A maximum and minimum temperature of 3.8ºC and 3.3ºC were recorded, respectively. This is problematic, as protocol dictates that during the Forced Cooling stage, the temperature of the blueberries should be lowered to and maintained at 0ºC. Since protocol was not followed, the assumption can be made that temperature spikes and breaks occurred after the Forced Cooling stage. Furthermore, the overall score of the pallet was graded as "Green Fail". The reason provided for the pallet being classified as "Green Fail", as described by the Fail Defects category, was that the boxes were underweight. If not for the fact that the boxes were underweight the pallet would have been classified as "Green", since the total defects recorded were below 5%. As mentioned in section 4.2, a pallet is graded as "Green" when each quality parameter is within specification and the total defects are below 5%. The minor defects detected for the pallet, recorded at 3.1%, were due to stalk attached as well as shrivelled blueberries, while the major defect detected, recorded at 0.3%, was due to mould present on some blueberries.

Spade Lane

	Min	Max	Ave
Arrival Temperature	3.30	3.80	3.57

Product BLUEBERRY 3.5KG-BAG NOT APPLICABLE NRXX-3.5KG-BAG

	Pallet Reference	Received Qty	Variety	Harvest Date	Grower	Country	Minor %	Major %	Nil Tolerance	Minor Defects	Major Defects	Fail Defects	Nil Tolerance Defects
Green Fail	760091600208030295 Lot Number	312				ZA	3.1	0.3	0.0	Stalk Attached, Shrivel	Mould	underweight	

Figure 4.122: QC report for pallet 760091600208030295 (Farm A)
Source: Company X

4.11.1.2. Farm B

No quality control reports were received for the pallets associated with the trials conducted on Farm B.

4.11.1.3. Farm C

Figure 4.123 shows the quality control report retrieved for the blueberries harvested on Farm C. Both pallet 760091600208047583 and pallet 760091600208047989 were the EB9-2 blueberry variety packed in 4kg trays. Upon arrival, the average temperature recorded for both pallets were 1.2ºC. A maximum and minimum temperature of 1.4ºC and 1.1ºC were recorded, respectively. Both pallets were graded as "Red Fail". The fail defects for both pallets were due to underweight trays. The minor defects detected for pallet 760091600208047583 and pallet 760091600208047989, recorded at 10.8% and 10.0% respectively, and were due to stalk attached as well as shrivelled and soft blueberries. In addition, the major defects detected for pallet 760091600208047583 and 760091600208047989, recorded at 8.1% and 3.1% respectively, were due to collapsed blueberries and mould present on some blueberries. Both pallets were classified as “Red” due to the total defects found in a sample being more than 10%, as mentioned in section 4.2.

Spade Lane

	Min	Max	Ave
Arrival Temperature	1.10	1.40	1.20

Product BLUEBERRY 4KG NOT APPLICABLE NRXX-4KG

	Pallet Reference	Received Qty	Variety	Harvest Date	Grower	Country	Minor %	Major %	Nil Tolerance	Minor Defects	Major Defects	Fail Defects	Nil Tolerance Defects
Red Fail	760091600208047583 Lot Number	256		14/11/2019		ZA	10.8	8.1	0.0	soft, Shrivel, Stalk Attached	Mould, Collapse	underweight trays	
Red Fail	760091600208047989 Lot Number	256		14/11/2019		ZA	10.0	3.1	0.0	soft, Shrivel, Stalk Attached	Mould, Collapse	underweight trays	

Figure 4.123: QC report for pallet 760091600208047583 and pallet 760091600208047989 (Farm C)
Source: Company X

4.11.2. Gauteng

4.11.2.1. Farm D

Figure 4.124 is an overview of the quality control reports retrieved for the blueberries harvested on Farm D. Both pallets 060016510422750681 and 060016510422750759 were the EB9-2 blueberry variety packed in 3.5kg boxes. Upon arrival, a maximum and minimum temperature of 4.2ºC and 1.9ºC respectively, were recorded. The average temperature recorded for both pallets was 2.7ºC. This is problematic since a temperature break for blueberries is identified as any rise in temperature of 2°C above the product-appropriate set point, for longer than 30 minutes. During the Forced Cooling stage protocol dictates that blueberries should be forced cooled to 0°C. Therefore, the assumption can be made that the blueberries experienced temperature spikes or temperature breaks after the Forced Cooling stage. **Figure 4.124** shows that both pallets were graded as “Amber”. The reason provided for the downgrading of the pallets to “Amber” was due to the boxes being underweight. If not for the fact that the boxes were underweight, the pallets would have been classified as “Green”, since the total defects of both pallets were recorded as below 5%. Both pallets had no minor defects recorded. However, the percentage major defects recorded for pallets 060016510422750681 and 060016510422750759, were 1.51% and 1.29%, respectively. In addition, both pallets recorded an estimated yield of 96%. **Figures 4.125** and **4.126** show that the major defects for both pallets were due to collapsed blueberries as well as major shrivelling of the blueberries. **Figure 4.125** also shows that the average weight of the boxes and average sugar brix for pallet

060016510422750681 were 3455g and 11.81%, respectively. **Figure 4.126** shows that the average weight of boxes and average sugar brix for pallet 060016510422750759 were 3479g and 11.37%, respectively.

Temperature : Min 1.90; Max 4.20; Avg 2.70

Expected ETA : 09/10/2019 00:00:00
Received : 09/10/2019 08:13:55
Inspection Date : 09/10/2019 13:09:58

Product Details	ISS Pallet	Cust Pallet ID	Supplier Pallet	GGN Number /Grower	Harvest Date	End Customer	Packhouse	Organic	PLU	Minor	Major	Waste	QA Comments	Brix Avg %	Pressure Avg Kg	Maturity% 1 2 3 4 5	Total Defects	Est Yield	RAG
Blueberry 3.5kg Loose SSLRG			060016510422750681		7303			NO		0.0%	1.51%	0.00%	Amber due to underweights boxes.	11.81	0.00	0, 0, 0, 0, 0	1.5%	96.0%	AMBER 312
Blueberry 3.5kg Loose SSLRG			060016510422750759		7303			NO		0.0%	1.29%	0.00%	Amber due to underweights boxes.	11.37	0.00	0, 0, 0, 0, 0	1.3%	96.0%	AMBER 312

Figure 4.124: QC report for pallets 060016510422750681 and pallet 060016510422750759 (Farm D)
Source: Company X

Blueberry 3.5kg Loose

ISS Pallet ID :
Supplier Pallet ID : 060016510422750681
Customer Pallet ID :
Variety :
Grower :
GGN :
Orchard/Farm :
Harvest Date : 7303
Size/Calibre :
Lot Number :

Freshness Technology : N/A
Punnet / Pad Type : N/A / N/A
Outer : GENERIC CARTON
Brand :
Organic? : NO
PLU? :
End Customer :
DP :
Packhouse :
Inspector :

AMBER
Expected Qty 312
Received Qty 312
Total Defects : 1.51%
Estimated Yield : 96.00%

Box / Pack Weights : Avg 3455g ; Min 3241g; Max 3671g
Weight Readings : 3241 3341 3378 3425 3426 3465 3511 3528 3564 3671

Fruit Weights : Avg 3.00g
Sugar Brix : Avg 11.81% ; Min 10.60%; Max 13.10%
Brix Readings : 10.6 10.8 11.3 11.6 11.6 11.9 12.1 12.5 12.6 13.1
Size : Min 0; Max 0 Undersize 0.00%
Size Readings :
Maturity % : Stage1: 0 / Stage2: 0 / Stage3: 0 / Stage4: 0 / Stage5: 0
Pressures : Avg 0.00 ; Min 0.00 ; Max 0.00
Minor Defects : 0.00% Minor Fruit Count : 0
Minor Type :
Major Defects : 1.51% Major Fruit Count : 156
Major Type : Collapse 0.68% Major Shrivel 0.82%
Waste : 0.00% Waste Fruit Count : 0 Packs With Waste : 0
Waste Type :
Other Issues : Underweights Found
QA Comments :
Amber due to underweights boxes.

Packs/Fruits Inspected : 1
Boxes Inspected : 3

Figure 4.125: Extended QC report for pallets 060016510422750681 (Farm D)
Source: Company X

Blueberry 3.5kg Loose

ISS Pallet ID :
Supplier Pallet ID : 060016510422750759
Customer Pallet ID :
Variety :
Grower :
GGN :
Orchard/Farm :
Harvest Date : 7303
Size/Calibre :
Lot Number :

Freshness Technology : N/A
Punnet / Pad Type : N/A / N/A
Outer : GENERIC CARTON
Brand :
Organic? : NO
PLU? :
End Customer :
DP :
Packhouse :
Inspector :

AMBER
Expected Qty 249
Received Qty 312
Total Defects : 1.29%
Estimated Yield : 96.00%

Box / Pack Weights : Avg 3479g Min 3256g; Max 3671g
Weight Readings : 3256 3362 3378 3427 3467 3478 3541 3579 3633 3671

Fruit Weights : Avg 3.00g
Sugar Brix : Avg 11.37%; Min 10.30%; Max 12.70%
Brix Readings : 10.3 10.6 10.8 11.1 11.1 11.3 11.5 12.0 12.3 12.7

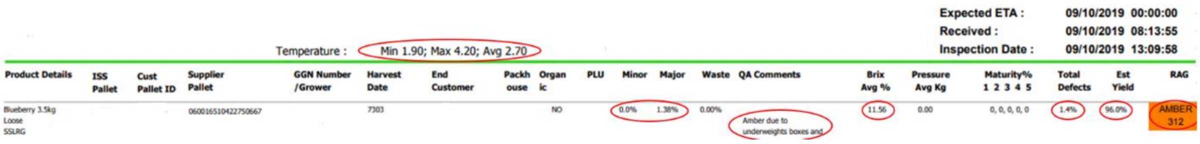
Size : Min 0; Max 0 Undersize 0.00%
Size Readings :
Maturity % : Stage1: 0 / Stage2: 0 / Stage3: 0 / Stage4: 0 / Stage5: 0
Pressures : Avg 0.00 ; Min 0.00 ; Max 0.00
Minor Defects : 0.00% Minor Fruit Count : 0
Minor Type :
Major Defects : 1.29% Major Fruit Count : 135
Major Type : Collapse 0.39% Major Shrivel 0.90%
Waste : 0.00% Waste Fruit Count : 0 Packs With Waste : 0
Waste Type :
Other Issues : Underweights Found
QA Comments :
Amber due to underweights boxes.

Packs/Fruits Inspected : 1
Boxes Inspected : 3

Figure 4.126: Extended QC report for pallets 060016510422750759 (Farm D)
Source: Company X

4.11.2.2. Farm E

Figures 4.127 and **4.128** show the quality control reports retrieved for the blueberries harvested on Farm E. The EB8-42 blueberry variety was packed in for pallet 060016510422750667, while the EB12-19 blueberry variety was packed for pallet 060016510422749920. The blueberries of both pallets were packed in 3.5kg boxes. **Figure 4.127** shows that upon arrival, the average temperature recorded for pallet 060016510422750667 was 2.7ºC. A maximum and minimum temperature of 4.2ºC and 1.9ºC, respectively, were recorded for the same pallet. **Figure 4.128** shows that upon arrival the average temperature recorded for pallet 060016510422749920 was 3.33ºC. A maximum and minimum temperature of 4ºC and 2.3ºC respectively, were recorded for the same pallet. This is problematic, as protocol dictates that the temperature of the blueberries should be lowered to and maintained at 0ºC during the Forced Cooling stage. As a result, temperature spikes and temperature breaks could have occurred after the Forced Cooling stage. The overall score for both pallets were graded as "Amber". The reason provided for pallet 060016510422750667 being classified as "Amber", was that the boxes were underweight. If not for the fact that the boxes were underweight, the pallet would have been classified as "Green", since the total defects recorded were below 5%. Pallet 060016510422750667 had no minor defects detected, while the major defects detected were recorded at 1.38%. As shown in **Figure 4.127**, the pallet recorded total defects of 1.38% and recorded an estimated yield of 96%. **Figure 4.128** shows that Pallet 060016510422749920 recorded total defects of 5.1%, therefore, justifying the grading of "Amber". The minor defects detected for the pallet, recorded at 3.8%, were due to stalk attached and soft blueberries, while the major defects detected, recorded at 1.3%, were due to collapsed blueberries.



Expected ETA : 09/10/2019 00:00:00
Received : 09/10/2019 08:13:55
Inspection Date : 09/10/2019 13:09:58

Temperature : Min 1.90; Max 4.20; Avg 2.70

Product Details	ISS Pallet	Cust Pallet ID	Supplier Pallet	GGN Number /Grower	Harvest Date	End Customer	Packhouse	Organic	PLU	Minor	Major	Waste	QA Comments	Brix Avg %	Pressure Avg Kg	Maturity% 1 2 3 4 5	Total Defects	Est Yield	RAG
Blueberry 3.5kg Loose SSLRG			060016510422750667		7303			NO		0.0%	1.38%	0.00%	Amber due to underweights boxes and	11.56	0.00	0, 0, 0, 0, 0	1.4%	96.0%	AMBER 312

Figure 4.127: QC report for pallets 060016510422750667 (Farm E)
Source: Company X

08/10/2019
17:36:26

Spade Lane

	Min	Max	Ave
Arrival Temperature	2.30	4.00	3.33

Product **BLUEBERRY 3.5KG NOT APPLICABLE** **NRXX-3.5KG**

	Pallet Reference	Received Qty	Variety	Harvest Date	Grower	Country	Minor %	Major %	Nil Tolerance	Minor Defects	Major Defects	Fail Defects	Nil Tolerance Defects
Amber	060016510422749920	312				ZA	3.8	1.3	0.0	Softness, Stalk Attached	Collapse		

Figure 4.128: QC report for pallets 060016510422749920 (Farm E)
Source: Company X

4.11.2.3. Farm F

Figure 4.129 shows a summary of the quality control report retrieved for both pallets, whilst **Figure 4.130** and **Figure 4.131** are more detailed QC reports for pallet 060016510422750438 and pallet 060016510422750629, respectively. EB9-2 was the blueberry variety harvested by Farm F during the trials conducted by the researcher and was packed in 3.5kg boxes. **Figure 4.129** shows that upon arrival, the maximum, minimum and average temperature were recorded as 0ºC for both pallets. In addition, both pallets recorded an estimated yield of 96%. **Figure 4.130** shows that pallet 060016510422750438 was graded an overall score of “Amber”. The reason provided for the downgrading of the pallet from “Green” to “Amber” was due to the boxes being underweight and the presence of isolated mould on the blueberries. Furthermore, this pallet recorded total defects of 1.4%. Although no minor defects were detected, major defects and waste were detected, recorded at 1.15% and 0.30%, respectively. Collapsed and shrivelled blueberries were the reasons provided for the major defects, while mould caused the wastage percentile. **Figure 4.130** also shows that the average weight of the boxes and average sugar brix for pallet 060016510422750438 were 3433g and 11.95%, respectively. As shown in **Figure 4.131**, pallet 060016510422750629 was also downgraded to “Amber” due to the boxes being underweight and the presence of isolated mould. The pallet recorded total defects of 1.3%, with major defects accounting for 1.10% and waste accounting for 0.20%. Collapsed and shrivelled blueberries were provided as the reasons for the major defects, while mould was the reason given for the wastage percentile. Furthermore, **Figure 4.131** shows that the average weight of a box for pallet 060016510422750629 was 3464g, while the average sugar brix recorded was 11.04% for the same pallet.

Expected ETA : 08/10/2019 00:00:00
Received : 08/10/2019 12:21:15
Inspection Date : 08/10/2019 16:04:58

Temperature : Min 0.00; Max 0.00; Avg 0.00

Product Details	ISS Pallet	Cust Pallet ID	Supplier Pallet	GGN Number /Grower	Harvest Date	End Customer	Packhouse	Organic	PLU	Minor	Major	Waste	QA Comments	Brix Avg %	Pressure Avg Kg	Maturity% 1 2 3 4 5	Total Defects	Est Yield	RAG
Blueberry 3.5kg Loose SSLRG			060016510422750438		n/a			NO		0.0%	1.15%	0.30%	Amber due to underweights boxes , isolated mould found.	11.95	0.00	0, 0, 0, 0, 0	1.4%	96.0%	AMBER 312
Blueberry 3.5kg Loose SSLRG			060016510422750629		n/a			NO		0.0%	1.10%	0.20%	Amber due to underweights boxes, isolated mould found.	11.04	0.00	0, 0, 0, 0, 0	1.3%	96.0%	AMBER 312

Figure 4.129: QC report for pallets 060016510422750438 and pallet 060016510422750629 (Farm F)
Source: Company X

Blueberry 3.5kg Loose

ISS Pallet ID :
Supplier Pallet ID : 060016510422750438
Customer Pallet ID :
Variety :
Grower :
GGN :
Orchard/Farm :
Harvest Date : n/a
Size/Calibre :
Lot Number :

Freshness Technology : N/A
Punnet / Pad Type : N/A / N/A
Outer : GENERIC CARTON
Brand :
Organic? : NO
PLU? :
End Customer :
DP :
Packhouse :
Inspector :

AMBER
Expected Qty 167
Received Qty 312
Total Defects : 1.45%
Estimated Yield : 96.00%

Box / Pack Weights : Avg 3433g Min 3124g; Max 3641g
Weight Readings : 3124 3321 3356 3378 3436 3454 3521 3532 3568 3641

Fruit Weights : Avg 3.00g
Sugar Brix : Avg 11.95%; Min 10.60%; Max 14.20%
Brix Readings : 10.6 11.1 11.3 11.3 11.5 11.6 12.3 12.5 13.1 14.2
Size : Min 0; Max 0 Undersize 0.00%
Size Readings :
Maturity % : Stage1: 0 / Stage2: 0 / Stage3: 0 / Stage4: 0 / Stage5: 0
Pressures : Avg 0.00 ; Min 0.00 ; Max 0.00
Minor Defects : 0.00% Minor Fruit Count : 0
Minor Type :
Major Defects : 1.15% Major Fruit Count : 118
Major Type : Collapse 0.42% Major Shrivel 0.73%
Waste : 0.30% Waste Fruit Count : 31 Packs With Waste : 0
Waste Type : Mould 0.30%
Other Issues : Underweights Found
QA Comments : Amber due to underweights boxes , isolated mould found.

Packs/Fruits Inspected : 1
Boxes Inspected : 3

Figure 4.130: Extended QC report for pallets 060016510422750438 (Farm F)
Source: Company X

Blueberry 3.5kg Loose

ISS Pallet ID :

Supplier Pallet ID : 060016510422750629

Customer Pallet ID :

Variety :

Grower :

GGN :

Orchard/Farm :

Harvest Date : n/a

Size/Calibre :

Lot Number :

Freshness Technology : N/A

Punnet / Pad Type : N/A / N/A

Outer : GENERIC CARTON

Brand :

Organic? : NO

PLU? :

End Customer :

DP :

Packhouse :

Inspector :

AMBER

Expected Qty 312

Received Qty 312

Total Defects : 1.30%

Estimated Yield : 96.00%

Box / Pack Weights Avg 3464g Min 3325g; Max 3611g

Weight Readings : 3325 3327 3371 3428 3437 3444 3561 3561 3571 3611

Fruit Weights : Avg 3.00g

Sugar Brix Avg 11.04% Min 10.30%; Max 12.10%

Brix Readings : 10.3 10.3 10.4 10.6 10.8 11.3 11.4 11.6 11.6 12.1

Size : Min 0; Max 0 Undersize 0.00%

Size Readings :

Maturity % : Stage1: 0 / Stage2: 0 / Stage3: 0 / Stage4: 0 / Stage5: 0

Pressures : Avg 0.00 ; Min 0.00 ; Max 0.00

Minor Defects : 0.00% Minor Fruit Count : 0

Minor Type :

Major Defects : 1.10% Major Fruit Count : 114

Major Type : Collapse 0.38% Major Shrivel 0.72%

Waste : 0.20% Waste Fruit Count : 21 Packs With Waste : 0

Waste Type : Mould 0.20%

Other Issues : Underweights Found

QA Comments : Amber due to underweights boxes, isolated mould found.

Packs/Fruits Inspected : 1

Boxes Inspected : 3

Figure 4.131: Extended QC report for pallets 060016510422750629 (Farm F)
Source: Company X

4.12. Conclusion

This chapter presented interesting viewpoints that were gathered during interviews conducted with key role players within the initial stages of the blueberry supply chain. Furthermore, it revealed the different opinions that individuals can have within the same industry. The researcher was able to identify various temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks that occurred during the trials conducted in the Western Cape and Gauteng. Furthermore, it was evident that protocols were breached on a regular basis and were emphasised by the researcher in this chapter. The researcher tried, as far as possible, to provide possible reasons for the above-mentioned temperature fluctuations and breach of protocols. It is important to mention, that areas which always adhered to protocols and never recorded temperature fluctuations, were also identified by the researcher and should be used as a benchmark by Company X moving forward.

Chapter 5: Interpretation

5.1. Introduction

In this chapter, the results identified in Chapter 4 are examined, discussed and interpreted by the researcher. This chapter highlights the main findings and provides possible reasons for these findings. Furthermore, the researcher focuses on major areas of concern and attempts to identify results that could assist in providing answers to the research questions.

5.2. Main findings regarding Average Time Spent per Stage

5.2.1. Harvest and Transportation stage

Some of the trials conducted on Farms A, D and F showed that it was possible to complete the Harvest and Transportation stage within 80 minutes, as set out in the protocols of Company X. Farm D2 was the only farm that managed to complete this stage within the protocol time for all three trials. Due to this finding, it is evident that more emphasis needs to be placed on implementing efficient procedures on the farms. During an interview, the manager of Farm D emphasized having enough tractor-trailers to ensure a fast turnaround time between the field and the cold room. Farms B, C and E were not able to complete a single trial within the protocol time provided for this stage, averaging times of 2.11, 2.58 and 6.22 hours, respectively. One of the reasons why Farm C did not complete the stage within the protocol time was due to rainfall that suspended the harvest for approximately 10-15 minutes. Another possible reason could be because Farm C made use of field packing, where they harvested into three-litre buckets instead of one-litre buckets. Sorting was also performed twice on Farm C instead of once like on all the other farms forming part of this study. On Farm E, protocol was not followed, as harvested fruit should be delivered to the cold room on a regular basis. Tractor-trailers delivered harvested fruit to the cold room on only two occasions, which resulted in an average time of 6.22 hours for the Harvest and Transportation stage. It is, therefore, evident that major changes need to be made, especially on Farm E, to help improve the time spent during the Harvest and Transportation stage. International Blueberry Specialist (2020) suggested that the time of harvest and the time crates arrive at the cold room should be more strictly managed to ensure that farms comply with protocols.

5.2.2. Pre-Cooling stage

All the farms except Farm C complied with the Pre-Cooling stage protocols, as set out by Company X. The protocols dictate that pre-cooling (forced air cooling) should be applied for at least three to five hours or until the pallets reach a pulp temperature of 6˚C. Although the Early Morning trial of Farm C did receive 3.17 hours of pre-cooling, room cooling was used instead of forced air cooling. This is not ideal, since forced air cooling drastically reduces the cooling time (by ten times or more) compared to room cooling (Elansari *et al.,* 2019:170) and is the preferred pre-cooling method. Therefore, the assumption is made that insufficient pre-cooling was applied. It is important to mention that insufficient pre-cooling could lead to a rise in temperature at a later stage along the cold chain and can subsequently reduce the quality of the product or even shorten its shelf life. The reason for this short pre-cooling time was due to a reefer truck that arrived at the farm to collect pallets for transportation to the packhouse. Instead of taking only sufficiently cooled pallets, the workers were instructed to load as many pallets as possible. The Late Morning and Afternoon trials for Farm C both received 17.92 hours of pre-cooling (room cooling).

5.2.3. Transportation to Packhouse stage

This stage is dependent on three variables namely, 1) the distance between the farm and the packhouse, 2) whether the farmers make use of shared transportation and 3) how much traffic there is on the road. Taking the above-mentioned factors into account, the average duration for this stage in the Western Cape was a time of 3.69 hours while the same stage in Gauteng lasted an average time of 2.73 hours.

5.2.4. Packhouse stage

Farm C made use of field packing, which resulted in a total of ten minutes spent inside the Packhouse stage, as no sorting and packing was necessary. Protocol dictates that approximately 40 minutes should be allocated to time spent during the Packhouse stage. Twenty (20) minutes are set aside for the receiving and weighing of pallets, measuring of pallet temperatures and a quick inspection. Hereafter, pallets are placed in a cold room to be packed. The remaining 20 minutes are set aside for the packing of blueberries, whereafter packed pallets are moved to a cold room ready for transportation to the cold store to receive forced air cooling. Although the above mentioned procedures are correct regarding the time spent on the blueberries specifically, not all factors are taken into consideration, as the time spent in this stage is dependent on various external factors such as: 1) *Time of the season* (during peak season the packhouse cannot manage with the high volumes causing a queue compared to the beginning of the season where more blueberries need to be received to complete a pallet) 2) *Packing schedules and markets* (for example, if the packhouse is packing EB8-42 punnets for the local market instead of 3kg EB12-19 boxes for the export market) 3) *Approval of the PPECB* (sometimes employees from the PPECB only arrive in the afternoon or do not approve a specific pallet, resulting in the need to re-package pallets) 4) *Availability of transportation to the cold room as well as schedules of the cold room for forced air cooling to be applied.* Any one or a combination of the above-mentioned external factors could be a reason for the extended time spent during the Packhouse stage. According to the protocol as set out by Company X, all the farms, except Farm C, spent too much time in the Packhouse stage. Farm E spent the shortest time (with the exception of Farm C) in this stage with an average time of 7.08 hours, while Farm D spent the longest time in this stage with an average time of 33.75 hours.

5.2.5. Transportation to Forced Cooling stage

As mentioned in section 4.6 of Chapter 4, the Transportation to Forced Cooling stage begins as soon as the pallets are loaded into the reefer trucks and stops as soon as the forced air cooling machines are switched on. In the Western Cape, the cold room is situated at the same location as the packhouse and could be a reason for the short average times of 25.2 and 24.2 minutes spent in this stage for Farms A and B, respectively. Another reason could be because the packhouse and cold store are managed by the same company, therefore, simplifying the procedures and causing less confusion with packaging or cooling schedules. Farm C spent an average time of 2.14 hours during the Transportation to Forced Cooling stage. This time makes sense as their field packed blueberries get weighed and inspected in the cold store by Company X and the PPECB and not at the packhouse. In contrast, the farms in Gauteng had to transport pallets to the cold store, which is located approximately 10km from the packhouse. The cold store is also owned by a company independent from the packhouse, hence, the packhouse had to rely on open slots and consequently, had less control over when forced cooling was applied to the pallets. The above-mentioned points could be reasons for the long average time of 15 hours spent during this stage for both Farms D1 and E as well as Farm F, which spent an average time of 9.42 hours during the Transportation to Forced Cooling stage.

5.2.6. Forced Cooling stage

Protocol dictates that forced air cooling should be applied for ten hours or until the pallet reaches the required pulp temperature of 0˚C. If sufficiently cooled, the pallets are placed in cold rooms to maintain the temperature. Ideally, pallets should be loaded for exportation as soon as forced air cooling is complete. During the Forced Cooling stage, Farm A spent the longest average time of 57.67 hours, while the Late Morning and Afternoon trials of Farm C spent the shortest average time of 15.67 hours in the same stage. The reason for the large time difference between the farms and the long period spent in the Forced Cooling stage, could be because the time spent during this stage is dependent on whether transportation is available to transport pallets to the local market or an airport/deep-sea port for exportation.

5.2.7. Total Time spent per stage

Protocol dictates that the beginning stages of the blueberry cold chain should be completed within 2120 minutes (35.33 hours). To be more specific, no more than 35.33 hours should pass from when the blueberries are harvested up until the pallets are loaded for transportation to an airport/deep-sea port. This is highly unrealistic as not one farm came close to the protocol time, as various external factors play a role as discussed above. Of the farms that made use of conventional packaging, and not field packing, Farm D1 had the longest total average time of 110.05 hours for the beginning stages of the blueberry supply chain, while Farm E had the shortest average total time of 75.64 hours. Farm C made use of field packing and recorded an average total time of 42.22 hours, which was the closest to protocol time out of all the farms. This could be linked to the fact that Farm C was able to bypass the Packhouse stage while the other farms had to still complete this stage.

5.3. Main Findings regarding Temperature Spikes and Temperature Breaks Recorded

5.3.1. Western Cape and Gauteng

As mentioned in the Temperature Spikes and Temperature Breaks section of Chapter 4, the Western Cape (Farms A-C) recorded a total of 260 temperature spikes, 48 temperature breaks, 345 chilling injury spikes and 25 chilling injury breaks. The three main stages of concern regarding temperature fluctuations in the Western Cape are the Harvest and Transportation, Packhouse and Forced Cooling stages. In contrast, the Pre-Cooling, Transportation to

Packhouse and Transportation to Forced Cooling stages had very few recorded temperature fluctuations. The Pre-Cooling stage recorded only two temperature spikes. A possible reason for these 15-minute-long temperature spikes could be due to warm pallets that were placed next to the pallets of the Late Morning trial, causing temperatures to rise. The Transportation to Packhouse stage recorded five temperature spikes and four temperature breaks. The absence of a separate holding room and loading bay could be possible reasons for the rise in temperatures observed. Another possible reason for the observed temperature spikes and temperature breaks could be due to the reefer truck not being properly cooled before loading the pallets. Lastly, the Transportation to Forced Cooling stage did not record any fluctuations in temperature.

Gauteng (Farms D-F) recorded a total of 378 temperature spikes, 194 temperature breaks, 0 chilling injury spikes and two chilling injury breaks. The five main stages of concern in terms of temperature fluctuations in Gauteng were the Harvest and Transportation, Packhouse, Transportation to Forced Cooling and Forced Cooling stages. In addition, the Pre-Cooling stage on specifically Farm F was of major concern. With the exception of Farm F, the Pre-Cooling stage had very few temperature breaks, with only one temperature break recorded on Farm D2. This temperature break continued for 515 minutes (8.6 hours), reaching the highest temperature of 13.1ºC for the Early Morning trial. During pre-cooling, temperatures started to decrease but eventually rose again. Since the iButton® involved, did manage to reach the specific protocol temperature, what followed had to be recorded as a temperature break. Lastly, the Transportation to Packhouse stage did not record any fluctuations in temperature.

5.3.1.1. Concern 1: High harvesting temperatures

On Farms A and B in the Western Cape, a total of 22 temperature spikes and 37 temperature breaks were recorded during the Harvest and Transportation stage. Whereas on the three farms in Gauteng, a total of 25 temperature spikes and 55 temperature breaks were recorded.

Farm C did not record any temperature spikes or temperature breaks during the Harvest and Transportation stage, since the weather was cool on the day of harvest. Protocol dictates that blueberries should not be harvested in temperatures of 30ºC or higher (Cold Chain Specialist, 2019). Therefore, Farm B, E and F did not follow protocol for the Late Morning and Afternoon trials, as is evident by the high number of temperature spikes and temperature breaks recorded.

Protocol was not followed on several of the farms in Gauteng and the Western Cape. On Farm A, one-litre buckets and empty crates stood in the sun before being used. In addition, due to broken gazebos, QC was performed in the sun on steel tables, which are known to be a conductor of heat. Crates full of blueberries were also placed in the sun instead of in the shade. On Farm B, empty crates and one-litre buckets were left in the sun over lunch. After lunch, the temperature of a one-litre bucket was recorded at 38.1ºC.

Furthermore, on Farm D2, empty crates and one-litre buckets were also left standing in the sun, recording temperatures of 31.2ºC and 34.6ºC, respectively. Whereas empty crates were removed from the trailer and placed on the steel table (in the sun), long before they were used on Farm E. Furthermore, one of the QC steel tables was without a gazebo and recorded a temperature of 47.7ºC. Lastly, Farm F did not follow protocol as empty crates stood in the sun instead of in the shade. Interestingly, the researcher found that Farm F recorded far fewer temperature spikes and temperature breaks than Farm E, although the fruit was harvested in the exact same conditions with the two farms in close proximity. The first reason for this could be because Farm F was able to ensure a much shorter turnaround time between the field and the cold room. The second reason could be due to the generator-powered trailer used to store and transport blueberries from the field to the cold room. Lastly, it should be mentioned that the Late Morning and Afternoon trials of Farm F started at 09:10 and 13:00, respectively. Whereas the Late Morning and Afternoon trials of Farm E only started at 13:30 and 15:00. Therefore, once again emphasising the importance of harvesting in cool temperatures.

The temperature spikes and breaks recorded on Farms A, B, D and E emphasize the importance of keeping empty one-litre buckets and crates in the shade, completing QC under gazebos and placing completed crates in the shade. The temperature spikes and temperature breaks recorded on Farm B, E and F emphasize the importance of following protocol by not harvesting during temperatures of 30ºC or higher, even if the farm is equipped with gazebos and other protocols are followed. In most cases, when a QC table was not equipped with a gazebo, the reason provided was because the gazebo broke due to strong wind.

Lastly, the researcher found that on all three farms in Gauteng as well as Farms A and B of the Western Cape, the Late Morning and Afternoon trials recorded the most fluctuations in temperature. This makes sense as temperatures during the day normally reaches its maximum over lunch time.

5.3.1.2. Concern 2: Pre-cooling on Farm F

All the farms, except Farm F, made use of the conventional forced-air cooling system as discussed in the Cold Store (Forced Cooling) section of Chapter 2. On Farm F, pre-cooling was applied by placing pallets inside a container-shaped cooler and subsequently applying forced-air cooling. During the Pre-Cooling stage, a total of ten temperature breaks were recorded on Farm F, with the longest temperature break lasting 165 minutes (2.75 hours) and reaching a maximum recorded temperature of 10.6ºC. One of the reasons for these temperature breaks could be because the container-shaped cooler has a door that requires it to be opened and closed every time pallets are placed inside or removed from the cooler. Whereas with the conventional forced-air cooling systems, pallets can be placed against or removed from the pre-cooling system without affecting the cooling process of other pallets. Another reason that might explain the exponential rise in temperatures could be due to warm pallets received from the field being placed directly in the cooler with pallets that are in the process of being forced-air cooled.

5.3.1.3. Concern 3: Inconsistent temperatures during the Packhouse stage

During the Packhouse stage in the Western Cape, a total of 27 temperature spikes were recorded for Farms A and B, while Farm A recorded 17 chilling injury spikes and two chilling injury breaks. The same stage in Gauteng recorded a total of 96 temperature spikes and 91 temperature breaks. In the Western Cape, the packing room was the main area of concern, although focus needs to be placed on the cold rooms as well. In Gauteng, the holding room and packing room were two areas of concern for this stage. Protocol dictates that the holding room, packing room and cold room maintain a temperature of 6ºC.

The holding room where pallets are received, weighed, temperatures are measured and inspections are carried out experienced an evident rise in temperature. In Gauteng, Farms E and F recorded temperature spikes and temperature breaks while pallets were in the holding room. This makes sense as the researcher recorded a temperature of 8.3ºC in the holding room after offloading was complete.

In the Western Cape, all the temperature spikes recorded for Farm A and most of the temperature spikes recorded for Farm B occurred while the crates were in the packing room. This makes sense as the researcher recorded a temperature of 9.6ºC inside the packing room. Furthermore, three trials for Farms D-F in Gauteng recorded temperature spikes, while some recorded temperature breaks when the pallets entered the packing room. During packaging, a maximum temperature of 18.2ºC and 13.7ºC were recorded for the Afternoon trial for Farm D1 and Farm E, respectively. A clear rise in temperature was also observed in the data for Farm F. As was the case in the Western Cape, a possible reason for the fluctuations in temperature could be due to the high temperature of 9.2ºC, 9.7ºC and 9.3ºC recorded on three separate days by the researcher.

In the Western Cape, all three trials for Farm A experienced very low temperatures whilst in the cold room, after the pallets were completed. Instead of maintaining temperatures, chilling injury spikes and chilling injury breaks were recorded. A minimum temperature of -1.8ºC was recorded for the Afternoon trial, while a minimum temperature of -2.2ºC was recorded for the Early Morning trial.

In conclusion, the researcher found that after all the doors of the holding room were closed, the temperature of the holding room recovered to 5ºC after a few minutes. This rise in temperature is unnecessary as it could have been prevented and can possibly lead to pallets being downgraded. Furthermore, if the packhouse in Gauteng is compared to the packhouse in the Western Cape, the packing room was much smaller and had limited space to move around in. What is worrying is the fact that the researcher was clearly able to tell that temperatures were not at the desired protocol temperature of 6ºC inside the packing room. Therefore, more emphasis needs to be placed on complying with protocols and maintaining cool temperatures when blueberries enter the packing room in both the Western Cape and Gauteng. Lastly, better control needs to be maintained over temperatures in the cold room and procedures need to be implemented to prevent pallets from experiencing chilling injury spikes or chilling injury breaks while waiting to be transported to the forced cooling location. A possible solution could be to further investigate field packing and the viability thereof, as Farm C only spent ten minutes during this stage and did not record any fluctuation in temperature.

5.3.1.4. Concern 4: Transportation to Forced Cooler

During the Transportation to Forced Cooler stage, a total of 42 temperature spikes and two temperature breaks were recorded on Farms D1, E and F. Fluctuations in temperature occurred on mainly two occasions during this stage.

Firstly, during the loading of pallets, Farm E recorded temperature spikes for all three trials while the Late Morning trial also recorded a temperature break. Temperature spikes were also recorded for the Late Morning trial of Farm F. In addition, all the pallets loaded on the evening of 11 September, recorded a fluctuation in temperature during the loading process. A possible reason for the rise in temperatures could be due to the fact that the doors connecting the holding room to the outside area stood open while the pallets were being loaded. This caused warm air from outside to enter the holding room area. Protocol was, thus, not followed and better control needs to be exercised in the future. Furthermore, the packhouse is not equipped with a loading bay and the air-lock system does not fit onto the reefer truck, which could be contributing factors.

Secondly, all three farms experienced temperature spikes during the offloading of pallets at the forced cooler. Protocol dictates that pallets should be offloaded in a cold room that maintains a temperature of 6ºC. Protocol was not followed when pallets were offloaded on the evening of 11 September, as the pallets were offloaded at a loading bay that was situated outside. The researcher recorded a temperature of 22.3ºC during offloading and this could be a reason for the temperature spikes recorded. After offloading a pallet, it was weighed and moved to a holding room. Protocol dictates that a temperature of 6ºC should be maintained while pallets are weighed and placed in a holding room. The weighing area and holding room do not function as a cold room and, therefore, protocol was not followed. Consequently, it makes sense that temperature spikes were recorded during the evening of 11 September.

On the morning of 12 September no temperature spikes or breaks were recorded during the Transportation to Forced Cooler stage as the loading bay and air-lock system were used during the offloading of the pallets. Furthermore, the pallets were offloaded into a cold room. In contrast to the previous day, protocol was followed. The pallets were moved from the cold room, weighed, and then transported through the holding room to the forced cooling room. The pallet did not remain stationary in the holding room. It is, thus, evident that if protocol is not followed temperature spikes and temperature breaks can occur.

5.3.1.5. Concern 5: Inconsistent temperatures during the Forced Cooling stage

The Forced Cooling stage recorded the most fluctuations out of all the stages for both the Western Cape and Gauteng trials. In the Western Cape, a total of 204 temperature spikes, seven temperature breaks, 328 chilling injury spikes and 23 chilling injury breaks were recorded. While in Gauteng, a total of 215 temperature spikes, 35 temperature breaks and two chilling injury breaks were recorded.

Various iButtons® recorded temperature spikes and temperature breaks simultaneously, with temperature fluctuations occurring in waves. The reason for this was owing to the defrosting cycles of the forced cooling machine (Cold Chain Specialist, 2019). Farms A, B, D1 and E experienced these defrosting cycles, which contributed to most of the temperature spikes and temperature breaks recorded.

In the Western Cape, specifically for Farm A, most of the chilling injury spikes occurred at the beginning of the Forced Cooling stage. These chilling injury spikes and breaks could be a result of the low temperatures that were maintained in the cold room, while in the Packhouse stage. Farm C recorded a total of 46 temperature spikes. Thirty-two (32) temperature spikes and seven temperature breaks were recorded for the Early Morning trial for Farm C. As discussed in the Data Analysis section of Chapter 4, the Early Morning trial's pallets entered the Forced Cooling stage a day before the Late Morning and Afternoon trials. Therefore, most of the temperature spikes and temperature breaks recorded for the Early Morning trial occurred after the first forced cooling session and before forced cooling was applied for a second time. After investigation, it was found that the fluctuations in temperature were recorded while the pallets of the Late Morning and Afternoon trials were being moved into the forced cooling tunnel. It should also be mentioned that Farm C made use of field packing. Therefore, the possibility exists that the pallets might be more susceptible to temperature fluctuations due to the lack of packaging.

In Gauteng, Farm E recorded a total of 81 temperature spikes and five temperature breaks. All five temperature breaks occurred owing to the iButtons® experiencing very low temperatures during the Transportation to Forced Cooler stage and, therefore, increasing when entering the Forced Cooler stage. All three temperature breaks recorded for the Afternoon 2 trial of Farm F, were recorded on a single iButton®. As with Farm E, the iButtons® experienced very low temperatures during the Transportation to Forced Cooler stage and could be a reason why the temperatures increased when entering the Forced Cooler stage.

In conclusion, the temperature that the pallets arrive in at the cold store could play a role when the Forced Cooling stage commences. In the Western Cape, cold temperatures upon arrival caused chilling injury spikes and chilling injury breaks. Whereas in Gauteng, cold temperatures upon arrival caused temperature spikes and temperature breaks. A possible reason for this could be that the forced cooling applied in the Western Cape is more intense than that of Gauteng as was evident in the Time and Stage Forced Cooling was reached section of Chapter 4. Furthermore, defrosting cycles are a major concern that needs to be addressed in both the Western Cape and Gauteng.

5.4. Main findings regarding the Time and Stage at which Protocol Temperature was reached

5.4.1. Pre-Cooling

The protocol of Company X dictates that pre-cooling should lower the pulp temperature of the blueberries to below 6ºC within 300 minutes (5 hours) after pre-cooling commences. Given the protocols of Company X, the protocol temperature is expected to be reached during the Pre-Cooling stage of the blueberry cold chain.

All three farms in the Western Cape failed to reach the protocol temperature within the required 300 minutes (according to the protocols), in terms of their average and median times. Furthermore, none of the farms managed to reach protocol temperature during the Pre-Cooling stage for all three trials. Farm C recorded the best results with the Late Morning and Afternoon trials reaching protocol temperature during the Pre-Cooling stage. It should be mentioned that if forced-air cooling was applied on Farm C, instead of room cooling, the above-mentioned protocols could possibly have been reached.

The average and median times of Farms E and F, in Gauteng, managed to reach protocol temperature within the protocol time of 300 minutes, while both trials conducted on Farm D failed to do so. All the trials conducted for the farms in Gauteng, except the Late Morning and Afternoon trials of Farm D2, reached protocol temperature during the Pre-Cooling stage.

Compared to the farms in the Western Cape, the pre-cooling performed in Gauteng is much more efficient and effective. One of the main reasons that the farms in Gauteng reached protocol temperature during the Pre-Cooling stage could be attributed to all three farms having pre-cooling rooms that are separate from the cold rooms. In other words, the cold room where pallets are built were separate from the room where pre-cooling was applied. Another reason could be that the holding room was separate from the pre-cooling room. After pre-cooling was applied, pallets were moved to a holding room where temperatures were maintained and, therefore, pallets were not susceptible to possible temperature fluctuations. Therefore, in order for Farms A and B to improve the efficiency and effectiveness of their Pre-Cooling stage, adding the above-mentioned facilities would be a good start.

5.4.2. Forced Cooling

Forced cooling is applied until the pulp temperature of the blueberries reaches a protocol temperature of 0ºC. The protocol of Company X dictates that as soon as forced cooling commences, the pulp temperature should reach protocol temperature within 600 minutes (10 hours). Since the Forced Cooling stage is the last stage of the beginning stages of the blueberry supply chain, it is expected that the blueberries should reach protocol temperature during this stage.

All the farms in the Western Cape reached the protocol temperature within the required 600 minutes (according to the protocols), in terms of their average and median times. All the farms in the Western Cape, except five iButtons® from Farm A, reached the protocol temperature during the Forced Cooling stage. Of the five iButtons®, one iButton® never reached protocol temperature, while four iButtons® reached protocol temperature during the Transportation to Forced Cooling stage.

Unlike the farms in the Western Cape, the farms in Gauteng all failed to reach the protocol temperature within the required time, in terms of their average and median times. Furthermore, twenty-two (22) iButtons® never reached protocol temperature, with each farm having at least four iButtons® that never reached protocol temperature. In addition, six iButtons® reached protocol temperature during the Transportation to Forced Cooling stage. This occurred for all three trials for Farm E, and the Early Morning and Afternoons trials for Farm F.

The Western Cape forced cooling process outperformed Gauteng in terms of efficiency and effectiveness. The forced cooling implemented in Gauteng was very inconsistent when referring to the efficiency and effectiveness of the forced cooling applied. A possible reason for these inconsistencies could be because of the distance between the packhouse and the forced cooling facilities. In the Western Cape, the packhouse and forced cooling facilities were situated on the same premises, therefore, minimizing the possibility of fluctuations in temperature. Another possible reason for the inconsistent forced cooling applied in Gauteng could be because Company X made use of an external company to apply forced cooling. Therefore, Company X had less control in terms of whether protocols were followed or not.

5.5. Main Findings regarding the Logistical Processes Used and Protocols not followed

On Farms D, E and F specific logistical processes were identified that should be used as a benchmark by Company X. Farm D spent the shortest time during the **Harvest and Transportation stage** when compared to all the farms trials that were conducted. Furthermore, a combination of Farms D and F should be used as both adhered to most of the protocols set in place. These farms also used their own ingenuity, as Farm D used peach pips to cover their roads most travelled, therefore, reducing the occurrence of dust. Farm F made use of a generator-powered trailer to prevent blueberry temperatures from rising further while in the field. It should be mentioned that Farm E had the best cold room facilities and procedures out of all the farm trials that were conducted and should be used as a benchmark in that regard.

Farm E should be used as the benchmark for pre-cooling, since not a single temperature spike or temperature break were recorded during the **Pre-Cooling stage** on Farm E. Furthermore, all the protocols were adhered to, as the pulp temperature of the blueberries were below 6ºC within 300 minutes (5 hours) and protocol temperature was reached in the Pre-Cooling stage.

The Gauteng leg of the **Transportation to Packhouse stage** should be used as a benchmark as not a single temperature spike or temperature break was recorded for this stage. By equipping the farms in the Western Cape with loading bays and air-lock systems fluctuations in temperature could possibly be reduced.

The packhouse in the Western Cape recorded far fewer temperature spikes and temperature breaks during the **Packhouse stage** than the packhouse in Gauteng. The packhouse in the Western Cape followed protocol more strictly, and thus, reaped the rewards. However, better control needs to be maintained over temperatures, and protocols need to be followed more strictly. It is important to mention the field packing used for Farm C, which allowed the pallets of Farm C to skip the Packhouse stage, spending only ten minutes inside the packhouse. This resulted in Farm C being the only farm not to record temperature spikes or temperature breaks during this stage. Furthermore, this caused Farm C to have a much shorter time spent in the beginning stages of the blueberry cold chain.

The Western Cape leg of the **Transportation to Forced Cooling stage** was identified as a benchmark, as not a single temperature spike or temperature break was recorded for this stage. The reason for this is owed to the forced cooling facilities and the packhouse situated at the same location. Therefore, if the same is possible in Gauteng, this would be the ideal situation as it is always more difficult to try and implement protocols at a company that has a wide variety of different products.

The Western Cape was also identified as a benchmark for the **Forced Cooling stage**, as forced cooling applied here was the most efficient and effective. However, the defrosting cycles is a big problem that needs to be investigated for both the Western Cape and Gauteng.

5.6. Main findings regarding the Temperature Profile of Various Geographical Locations

5.6.1. Western Cape

On both Farms A and B, the iButtons® recorded maximum harvesting temperatures above 30ºC for all three trials. It should be mentioned that Farm B was the only farm that recorded an average harvesting temperature above 30ºC. This is plausible as the SAWS recorded a maximum temperature of 34.7ºC for the same day. Both the Late Morning and Afternoon trials for Farm B recorded average harvesting temperatures of 34.8ºC and 32.8ºC, respectively. This is very concerning as protocol dictates that fruit should not be harvested in temperatures of 30ºC or higher. A notable trend for both Farms A and B were that the Late Morning and Afternoon trials recorded higher maximum and average harvesting temperatures compared to the Early Morning trials. After consultation with industry experts, it was determined that the reason for this phenomenon is because the fruits' temperature is directly proportional to the ambient temperature. The maximum harvesting temperatures recorded on Farm C support this opinion, as the Early Morning trial's temperatures were substantially warmer than the Late Morning and Afternoon trials' temperatures. The reason for this is because it started raining during the Early Morning trial, therefore, the fruits' core temperature cooled down, as is evident by the lower maximum harvesting temperatures recorded for the Late Morning and Afternoon trials on Farm C. In addition, the maximum harvesting temperature recorded for Farm C was during the Early Morning trial and was recorded prior to the rain. What is concerning in this case, is that for all three trials the iButtons® recorded temperatures between 6ºC and 21ºC warmer than those recorded by the SAWS. A possible reason for this could be because the temperatures recorded by the SAWS were not on the farms itself, but between 10km and 45km from the farm. In addition, it is important to note that the temperature readings provided by the SAWS are recorded in the shade, while the temperatures recorded by the iButtons® were often in direct sunlight. This can have a significant impact on the temperatures recorded.

Furthermore, it is the opinion of industry experts that the sun combined with the respiration of the fruit increases the fruits' temperature, which results in higher temperatures recorded by the iButtons®. The fact that on certain farms one-litre buckets and trays were left in the sun and placed on steel tables, which generates a lot of heat, does not help.

5.6.2. Gauteng

For the trials conducted in Gauteng, a maximum harvesting temperature higher than the protocol temperature of 30ºC was recorded during each trial, except the Early Morning trial of Farm F. A possible reason for this could be because the Early Morning trial for Farm F concluded at the same time as the Early Morning trials for Farms D2 and E started. This could contribute to the argument that it is better to harvest during the early morning, as the fruit temperature and day temperature are cooler. Farm D2 recorded average harvesting temperatures above 30ºC for the Afternoon trial, while Farm E recorded average harvesting temperatures above 30ºC for both the Late Morning and the Afternoon trials. For both Farms D2 and F, the Afternoon trials recorded the highest maximum and average harvesting temperatures. Farm E recorded its highest maximum and average temperatures during the Late Morning stage. It is noteworthy to mention, that for all the trials conducted in Gauteng, the highest maximum and average harvesting temperatures were recorded between 13:24 and 14:00. Ultimately, supporting the comment made above, that it is better to harvest during the early morning while it is still cool. Interestingly, the Late Morning trial for Farm F recorded a minimum harvesting temperature of 9ºC, which was cooler than the Early Morning and Afternoon trials temperatures of 17.5ºC and 26.8ºC, respectively. The reason for this is because Farm F made use of a cooling trailer. One iButton® experienced intense cooling, and therefore, a minimum temperature of 9ºC was recorded. It should be mentioned that the average harvesting temperatures for all the trials conducted on Farm F never exceeded the protocol temperature of 30ºC. The cooling trailer could have contributed to Farm F being the only farm in Gauteng to achieve this. In addition, the SAWS recorded a maximum temperature of 30.6ºC for this day on both Farms E and F. What is concerning is that for all three trials the iButtons® recorded temperatures between 8ºC and 12.7ºC warmer than that of the SAWS. A possible reason for this could be because the temperatures recorded by the SAWS were not on the farms itself but between 10km and 45km from the farm. In addition, it is important to note that the temperature readings provided by the SAWS are recorded in the shade, while the temperatures recorded by the iButtons® were often in direct sunlight. This can have a significant impact on the temperatures recorded. Furthermore, it is the opinion of industry experts that the sun combined with the respiration of the fruit increases the fruits' temperature, which results in higher temperatures recorded by the iButtons®. As with the Western Cape, the fact that on certain farms, buckets and trays were left in the sun and placed on steel tables that generate a lot of heat, does not help.

5.7. Quality Control

James, James & Evans (2006) state that after harvesting perishable produce, the rapid extraction of heat from the produce, referred to as pre-cooling, is critical to remove unwanted field heat. This is due to the fact that respiration rates rely on temperature, since high temperatures increase the rate of respiration (Elansari, Fenton & Callahan, 2019:162). The main goal of pre-cooling is to ensure a rapid decrease in the temperature of a product in product specific conditions, within a certain time period, given the space provided (Elansari, Fenton & Callahan, 2019:163). Therefore, pre-cooling can contribute to the preservation of quality and an increased shelf life. It is, thus, important that pre-cooling is applied effectively, as insufficient pre-cooling could lead to a rise in temperature further along the cold chain. Furthermore, Boyette *et al.*, (1996) state that a cold chain will only be effective if forced cooling is applied, as the effectiveness of cooling and not its availability, is the deciding factor in quality. For forced cooling to be applied effectively in the cold chain, it must be applied efficiently and constantly. Forced cooling is applied to try and eliminate the occurrence of temperature spikes or temperature breaks along the blueberry cold chain.

Table 5.1 shows that not a single farm received efficient and effective cooling during both the Pre-cooling and Forced Cooling stages. Therefore, the assumption can be made that quality issues might be evident on the quality reports.

Table 5.1: Point system for each farm regarding the effectiveness and efficiency of the pre-cooling and forced cooling applied

Point awarded for each farm in term of the cooling received during the Pre-Cooling and Forced Cooling stages						
X	All trials for the farm reached protocol temperature within the protocol time provided = 1 point					
Y	All trials for the farm reached protocol temperature during the required protocol stage = 1 point					
Z	Not a single temperature spike, temperature break, chilling injury spike or chilling injury break was recorded during the stage = 1 point					
Farms	**A**	**B**	**C**	**D**	**E**	**F**
Pre-Cooling (Rating out of 3)	Z	Z	-	-	X, Y, Z	X, Y
Forced Cooling (Rating out of 3)	X	X, Y	X, Y	-	-	-
Total score	2/6	3/6	2/6	0/6	3/6	2/6

Source: Compiled by the author for the purpose of the study, 2020

5.7.1. Temperature spikes and Temperature breaks after Forced cooling was applied

From the quality control reports, the researcher was able to determine that temperature spikes and/or temperature breaks occurred after the Forced Cooling stage, for Farms A, D and E. A temperature break for blueberries is identified as any rise in temperature of 2°C above the product-appropriate set point, for longer than 30 minutes. During the Forced Cooling stage, protocol dictates that blueberries should be forced cooled to 0°C. Therefore, the assumption can be made that the blueberries experienced temperature spikes and/or temperature breaks after the Forced Cooling stage as temperatures above 0°C were recorded. These fluctuations in temperature possibly contributed to the deterioration of fruit quality. However, the extent of the temperature fluctuations and the effect it had on the quality of the fruit cannot be determined.

5.7.2. Quality Control Reports

No quality control reports were received for the pallets associated with the trials conducted on Farm B.

5.7.2.1. Farms with pallets downgraded due to the boxes being underweight

The pallets for Farms A, D and E (Pallet: 060016510422750667) were downgraded to "Amber" due to the boxes being underweight, as described by the Fail Defects categories. If not for the fact that these boxes were underweight the pallets of Farms A, D and E would have been classified as "Green", since their total defects recorded were below 5%.

Possible reasons for the boxes being underweight could be due to moisture loss. The lack of the efficiency and effectiveness during the Pre-Cooling or Forced Cooling stages, as depicted in **Table 5.1**, could be a possible reason for this moisture loss. To the best of the researcher's knowledge, relative humidity was not maintained at 90-95% on these farms, which normally contributes to moisture loss (Van Amerongen, 2021). Another reason could be the large number of temperature fluctuations recorded in the beginning stages of the blueberry cold chain. Lastly, the temperature fluctuation that occurred after the Forced Cooling stage could also have contributed to the moisture loss.

5.7.2.2. Farms with pallets downgraded due to various reasons

Both pallets of Farm C were graded as "Red Fail". The fail defects for both pallets were due to underweight trays. The fact that both pallets recorded total defects of more than 10% contributed to the fact that these pallets were classified as "Red". The minor defects detected were due to stalk attached as well as shrivelled and soft blueberries. In addition, the major defects detected were due to collapsed blueberries and mould present on some blueberries.

Pallet 060016510422749920 of Farm E recorded total defects of 5.1%, therefore, justifying the grading of "Amber". The minor defects detected for the pallet were due to stalk attached and soft blueberries, while the major defects detected were due to collapsed blueberries.

Both pallets for Farm F were graded an overall score of “Amber”. The reason provided for the downgrading of the pallets from “Green” to “Amber” was due to the boxes being underweight and the presence of isolated mould on the blueberries.

Possible reasons for the boxes being underweight could be due to moisture loss. The lack of efficiency and effectiveness during the Pre-Cooling and/or Forced Cooling stages, as depicted in **Table 5.1**, could be a reason for this moisture loss. On Farm C, relative humidity was not maintained at 90-95% and could be a contributing factor to the moisture loss experienced (Van Amerongen, 2021). Another reason could be the large number of temperature fluctuations recorded during the beginning stages of the blueberry cold chain. During the Forced Cooling stage for Farm C, 25 chilling injury spikes and 21 chilling injury breaks were recorded that could have led to the shrivelling and soft blueberries. The minor defects such as stalk attached is seen as an unnecessary defect and can be eliminated if better control is maintained during harvest. The temperature fluctuations on each farm could have contributed to the moisture loss, soft and collapsed blueberries as well as isolated mould. Lastly, Farm C made use of field packing, therefore, the effects of insufficient cooling, as well as the presence of temperature fluctuations could have a bigger impact on the quality of the fruit.

5.8. Conclusion

The beginning stages of the blueberry supply chain of Company X are underperforming with regards to the following of protocols and prevention of temperature fluctuations. Various areas of concern were identified by the researcher with possible reasons given for each concern. Company X will have to act accordingly as it could potentially contribute to ensuring a better-quality product.

Chapter 6: Conclusion, Recommendations and Results

6.1. Introduction

The final chapter provides a summary of the research and determines whether the literature review, data analysis, interpretation of results and recommendations answer the research questions.

6.2. Concluding remarks

The main motive for this research was the growing concern of blueberry exporters regarding the increasing losses, both financially and in the quality of the fruit, while the product is in transit to its final destination. Haasbroek (2013) revealed that a decrease in the quality of products such as table grapes, apples, pears, and plums are mainly due to an ineffective export cold chain. The same assumption can be made for blueberries. Valentine & Goedhals-Gerber (2017:3) expanded on the findings of Haasbroek (2013) by proving that various factors could play a role in the decrease of quality in the first section of an apple supply chain. These factors include the geographical location of the farms, different methods of loading, offloading and transportation on and from farms to the centralised cold storage facility, and the trade-off between the time of picking and fruit quality. Therefore, Company X prompted an investigative enquiry into the cold chain of blueberries and identified concerns over, specifically, the beginning stages of this cold chain and the logistical processes followed. This study focused on identifying whether the different logistical processes and handling methods implemented, specifically in the beginning stages of the blueberry supply chain, from the picking process until after forced cooling is applied, have an influence on the quality of the fruit. The aim of the research was to identify where (if anywhere) temperature breaks occur along the beginning stages of a blueberry supply chain. A particular focus was placed on blueberries from farms in different districts in South Africa, namely Gauteng and the Western Cape. By identifying where temperature breaks (if any) occur along the beginning stages of a blueberry supply chain, it would enable Company X to minimize these breaks, thus, maximizing future profits. For this study, a temperature break was defined as "any rise in temperature of 2°C above the product-appropriate set point for longer than 30 minutes". Furthermore, if the temperature falls below -1.5°C for longer than 30 minutes, it was characterised as chilling injury. Lastly, when the temperature rises above the established 2°C or falls below the -1.5°C barrier, but does not last longer than 30 minutes, it was defined as a temperature spike and not a temperature break.

The literature review was conducted through secondary research. The literature review helped the researcher gain an overall understanding of blueberries regarding their origin and cultivar type, supply chain and protocols followed, cold chain and the importance thereof for perishable produce, international best practices, industry terms used and how quality control is performed. A particular focus was placed on the better understanding of each stage in the beginning stages of a blueberry supply chain and the handling methods and transportation systems used within each stage. Furthermore, the effect that temperature fluctuations could have on the overall quality of blueberries was also examined. Lastly, the geographical location of the fruit farms under investigation and the different times of harvest were examined to gain a better understanding.

In March 2019, the planning and initial arrangements of trials commenced. After ethical clearance was received in August 2019, qualitative and quantitative data collection were permitted and ensued from September to November 2019. Qualitative primary research (semi-structured interviews) was used to gain insight into international best practices, while qualitative analysis was performed through the means of informal observations and by conducting semi-structured interviews with each key role player in the beginning stages of the blueberry supply chain. Quantitative analysis was performed by conducting temperature trials on farms, packhouses, cold stores and during transportation between these facilities. Temperature monitoring devices (iButtons®) were placed between the fruit to measure the ambient temperature experienced by blueberries in intervals of five minutes. Recording started as soon as an iButton® was placed in a one-litre bucket during harvest and concluded after forced cooling was applied in the cold store. A power analysis determined that six trials, with a total of 54 iButtons® on each farm, were required for the research to be considered valid and reliable. Due to an error by the researcher, the trials conducted on Farm D had to be repeated. However, it should be mentioned that the first trial conducted on Farm D still had usable data. Therefore, at the completion of the seven trials (originally six), 312 of the 378 (83%) inserted devices provided usable data. Some of the iButtons® used in this study were second-hand and could possibly explain why 66 of the devices malfunctioned.

A study conducted by Fedeli (2019:145) on pome fruit and table grapes, illustrated that no cold chains are without their faults. The same assumption can be made for this study, as various significant temperature fluctuations occurred within the beginning stages of the blueberry supply chain. The temperature fluctuations were revealed to be mainly due to inefficient and ineffective logistical processes and handling techniques, pre-cooling and forced cooling not being applied effectively and efficiently, and the protocols of Company X not being adhered to. Recommendations to help improve the aforementioned areas are discussed in detail by the researcher in the recommendations section of Chapter 6.

The quality of fruit can be negatively impacted by fluctuations in temperature, since an increase in temperature leads to an increase in the rate at which the natural degrading process of perishable products occur, a decrease in the fruits' relative shelf-life and an increase in the percentage loss of fruit per day (Kitinoja, 2013). Therefore, it is the opinion of the researcher that the temperature fluctuations recorded during the beginning stages of the blueberry supply chain could have been avoided (or at least reduced) if protocols were followed more strictly. Furthermore, the researcher believes that these temperature fluctuations contributed to pallets being downgraded, as discussed in Chapters 4 and 5. One of the main reasons pallets were downgraded were due to them being underweight. Studies conducted by Kitinoja (2013) and James & James (2010:1950) respectively, showed that maintaining a good cold chain reduces transpiration as blueberries naturally start losing moisture as soon as they are harvested. In other words, a good cold chain reduces the occurrence of moisture loss, and thus, ensures less shrivelling. Van Amerongen (2021) states that cooling by means of through-flow cooling (forced-air cooling) reduces moisture loss and extends the shelf-life of blueberries. In addition, maintaining 90-95% relative humidity at an optimum temperature, further contributes to the reduction of moisture loss. The QC reports recording moisture loss (Chapter 4 and 5), ascribed insufficient pre-cooling and/or forced cooling applied as one of the possible reasons for the loss of moisture. In addition, to the best of the researcher's knowledge, relative humidity was not applied throughout the beginning stages of the blueberry supply chain. However, the researcher did observe several temperature fluctuations. Another contributing factor to the moisture loss recorded could be the temperature fluctuations recorded after the Forced Cooling stage. Therefore, the assumption can be made that all these factors could possibly cause moisture loss of blueberries. The researcher believes that effectively and efficiently applied pre-cooling and forced cooling combined with a controlled relative humidity and temperatures could drastically decrease the loss of moisture experienced by the fruit.

6.2.1. Did the study answer the research questions?

This sub-section focuses on each research question to determine whether it was answered during the study.

- *Do the **logistical processes**, in the beginning stages of the blueberry supply chain, from the picking process until the blueberries are loaded into cold storage, have an influence on the quality of the fruit?*

The Descriptive Data Analysis (Chapter 4) showed that several stages in the beginning stages of a blueberry supply chain did not adhere to protocols as discussed in the literature review (Chapter 2), with specific reference to the protocols that apply to logistical processes used. The Interpretations (Chapter 5) focussed on the main areas of concern regarding the application of logistical processes and whether temperature fluctuations occurred. It also shows the possible influence that these poorly applied logistical processes had on the quality of the fruit. The best performing candidate during each stage was also identified by the researcher in Chapter 5 and should be used as a benchmark by Company X. Lastly, recommendations on how to improve the logistical processes being used are discussed in the Recommendations, Conclusions and Results (Chapter 6) and, therefore, this research question is answered by the research.

- *Do the different **handling techniques** for loading, offloading and transportation on and from farms to the centralised packhouse facility, impact the temperature profile of blueberries?*

In the literature review (Chapter 2), the researcher discussed common handling techniques used in the blueberry industry as well as protocols prescribed by Company X regarding the handling of blueberries for this study. Descriptive Data Analysis (Chapter 4) discussed the various handling techniques used and temperature fluctuations recorded during each stage of the beginning stages of the blueberry supply chain. Many of the temperature fluctuations observed were ascribed to handling technique protocols not followed, while some temperature fluctuations were due to farms, packhouses and/or cold rooms not being equipped with the appropriate loading bays and airlock systems. The main concerns regarding the aforementioned statements were discussed in the Interpretations (Chapter 5). Lastly, possible recommendations regarding the handling techniques used are discussed in the Recommendations, Conclusions and Results (Chapter 6) and, therefore, this research question is answered by the research.

- *Do **temperature breaks** occur in the beginning stages of the blueberry supply chain, from the picking process until the blueberries are loaded into cold storage?*

The Descriptive Data Analysis (Chapter 4) identified temperature spikes, temperature breaks, chilling injury spikes and chilling injury breaks in each stage of the beginning stages of the blueberry supply chain, and therefore, answered this research question.

- *Does the **geographical location of farms** in the various districts have an impact on the temperature profile of blueberries?*

The Literature review (Chapter 2) provided a background regarding the various factors that need to be taken into consideration when looking at the effect that geographical locations have on fruit quality. The Descriptive Data Analysis (Chapter 4) discussed the different harvesting methods used, climatic conditions recorded by the SAWS, and temperatures recorded by the iButtons® on each farm. The Interpretations (Chapter 5) discussed the main concerns regarding the high maximum and average temperatures recorded by the iButtons® on each farm. Furthermore, possible reasons were provided for the substantial difference identified between the temperatures recorded by the SAWS and the iButtons®. Lastly, possible recommendations regarding the high temperatures recorded by the iButtons® are discussed in the Recommendations, Conclusions and Results (Chapter 6), and therefore, this research question was answered by the research.

- *Is there a link between the **time of harvesting and fruit quality**, specifically for the Southern highbush variety?*

The literature review (Chapter 2) provided a background regarding the ideal circumstances to harvest blueberries. Protocol dictates that blueberries should be harvested in temperatures between 10-30ºC. The Descriptive Data Analysis (Chapter 4) identified that temperature spikes and temperature breaks were recorded during the harvest of blueberries and identified that protocols were not followed on some farms. The Interpretations (Chapter 5) discussed the main concerns regarding the high harvesting temperatures recorded and could be a possible contributing factor to the downgrading of pallets. Lastly, possible recommendations regarding the handling techniques used are discussed in the Recommendations, Conclusions and Results (Chapter 6), and therefore, this research question was answered by the research.

6.3. Recommendations

The recommendations provided in this section attempt to provide Company X with a guideline regarding which areas in the initial stages of the blueberry cold chain should be focused on, which areas are excelling and how to possibly improve when underperforming. The researcher divided the recommendations into three sections namely: 1) short term (a quick solution, easy to implement, minor costs involved), 2) medium term (involves more planning and changes made in the way processes are implemented, few costs involved) and long term (implementation of infrastructure, purchasing equipment, more costs involved, longer time frame).

6.3.1. Short Term

Education on the significance of temperature in the blueberry cold chain

The majority of employees do not understand the significance of temperature in the blueberry cold chain. As mentioned in section 4.3, interviewees from each stage in the blueberry cold chain agreed that additional training of personnel would improve the blueberry cold chain. One interviewee mentioned that workers, managers and even owners do not always understand the importance of cooling or why specific protocols should be followed. Furthermore, they mentioned that training should be simplified and focus on specific areas. However, the main theme should be to continuously keep the temperature of blueberries as low as possible. It was suggested that if the positive effect that cooling has on blueberries could be translated into "monetary" worth, the invested individuals would gain a better understanding of what effect their role has on the outcome of the blueberry cold chain. In addition, it could have an impact on their own income if a better-quality product is produced.

Ensure protocols provided by Company X are adhered to

Emphasis needs to be placed on the importance of following the protocols as prescribed by Company X. If protocol dictates that blueberries should not be harvested in temperatures of 30ºC or higher, blueberry producers should strictly adhere to this. During the study, the researcher was able to identify the breach of protocols on numerous occasions in the beginning stages of the blueberry supply chain. For example, one-litre buckets and trays, used during harvesting, should not be left in the sun if not in use, the door of a room where cooling is applied or maintained should always be closed after entering or exiting, and pallets waiting to be loaded or after offloading should stand in a refrigerated holding room and not outside.

Although the above-mentioned can be seen as minor errors, the elimination thereof could have a significant impact on the quality and shelf-life of the product. Furthermore, in the case that a gazebo breaks due to strong winds, it is the opinion of the researcher that blueberry producers should have additional gazebos in stock, as QC stations should always be in a shaded area. Lastly, the researcher proved that a steel table generates substantially more heat than a plastic table. Therefore, plastic tables should be the standard table used at QC stations.

Continuous improvement of the blueberry cold chain temperature profile

Each role player in the beginning stages of the blueberry cold chain should have a mind-set of constantly wanting to improve their respective stages, specifically referring to the temperature profile of blueberries. This can be achieved by each role player identifying temperature sensitive areas/actions or writing reviews after each season to identify where improvement is required. Furthermore, more control should be exercised over the collection of detailed information during the season. More importantly, this information should be communicated and distributed to each role player in the blueberry cold chain within Company X, in order for these individuals to gain a better understanding of the blueberry cold chain in its entirety. This will enable personnel to act pro-actively rather than reactively. In section 5.5, the researcher identified areas where improvement is required as well as areas where role players excelled. This section should be examined by the appropriate personnel and can be used as a guideline.

Use a buffer to compensate for moisture loss

In section 5.6, the researcher identified that various pallets were downgraded due to boxes being underweight. The natural loss of moisture during transit could be one of the reasons for the boxes being underweight. A temporary solution to decrease the chances of a box being underweight upon arrival at the destination, could be to use a buffer when packing the boxes. After a discussion with an expert in the table grape industry, it was mentioned that the table grape industry makes use of a 2% buffer during packaging to compensate for moisture loss. In other words, if a table grape box is expected to weigh 3 500g, the box is packed to weigh 3 570g. The same principle could be used for blueberries.

6.3.2. Medium Term

Re-evaluating or adjusting protocols based on the information collected

It is the opinion of the researcher that some of the protocols as prescribed by Company X need to be re-evaluated to include factors previously not identified or to adjust protocols so that they are stricter or more realistic. For example, the protocol regarding the total time a blueberry can spend in the blueberry cold chain should be adjusted to include the existence of external factors such as packing schedules, availability of transportation, etc. In theory, this sounds like a simple solution, but in order for this to be realized, Company X will have to re-examine industry requirements, the company's expectations regarding blueberry standards and the producer's ability to fulfil the new protocols.

Reducing vibrations during transit and decreasing the occurrence of dust

Emphasis needs to be placed on minimizing the occurrence of dust and reducing vibrations when transporting the fruit on a tractor-trailer from the field to the cold room. Various implementations could be put in place to ensure smoother transport for the fruit as well as exposure to minimal dust. For example, on Farm D the road most travelled between the field and cold room was covered with peach pips while on Farm E the employees made use of a water bowser (a mobile water tank) to prevent the occurrence of dust on the gravel road. Tractor-trailers should be equipped with soft suspension, whereas the drivers thereof should be educated on why driving at a slower pace could have a positive effect in reducing vibrations and ensuring better fruit quality. In addition, a more expensive but long-lasting solution could be to tar the main road between the field and the cold room. However, if this is not feasible, farms should ensure that gravel roads are scraped regularly. Furthermore, a study by Eissa, Albaloushi & Azam, (2013:188) on apples during various vibration tests found that foam-net materials used in the form of a cushion, contributed to the fruit having less damage than the fruit without a cushion. Therefore, a foam-type material could be used as a cushion (layer) in crates to reduce vibrations and decrease the occurrence of bruising during transit. The end goal should be to ensure a smooth and dust-free ride from the field to the cold room.

Implementing a temperature profile responsibility agreement

The signing of a responsibility agreement could be a possible solution to ensure that all parties involved in the blueberry cold chain understand the importance of the temperature profile of the blueberries as set out in the protocols of Company X. The idea behind this agreement is to transfer responsibilities from one role player to another as the product moves along the blueberry cold chain. For example, when the transportation company loads pallets, the responsibility to comply with the temperature profile protocol shifts from the farmer to the transportation company. If the pallets arrive at the packhouse with an ambient temperature of 10ºC, instead of the expected 6ºC, the packhouse will be able to reject the pallet as the responsibility has shifted to the packhouse. Therefore, the transportation company will be liable for the costs of that pallet. In effect, this could create a chain reaction that can have a positive outcome on the temperature profile of the blueberries. To add to the above-mentioned example, the transportation company will have to ensure that their reefer trucks are up to standard and farms will be forced to ensure that their pallets are sufficiently pre-cooled.

Installing automated doors at the cold room facilities of the farms, packhouses and cold stores

The installation of automated doors at facilities where cold treatment is applicable could help improve the cold chain, as human error is one of the reasons why temperature fluctuations occurred. During the trials conducted, the researcher observed that on multiple occasions doors were left open or closed insufficiently for extended periods of time. On some occasions, employees did not have the capacity to close the door, as they were moving pallets, however, on other occasions neglect was the reason for the doors not being closed (properly). Having an automated door that closes after a certain length of time has passed should be installed at all the facilities where cold treatment is implemented.

6.3.3. Long Term

Improving the average time spent during the Harvest and Transportation stage per farm

Out of all the farms where trials were conducted on, only Farm D2 managed to complete this stage within the protocol time for all three trials. During an interview, the manager of Farm D emphasized being equipped with enough tractor-trailers to ensure a fast turnaround time between the field and the cold room. It is the opinion of the researcher that all the farms need to re-evaluate their processes used during the Harvest and Transportation stage, as Farm D proved that the protocols set out are realistic and attainable. Therefore, the addition of more tractor-trailers is recommended to ensure a faster turnaround time between the field and the cold room. In addition, International Blueberry Specialist (2020) suggested that the time of harvest and the time crates arrive at the cold room should be managed more strictly. Lastly, if not already equipped, farmers should consider installing shaded areas where the offloading of harvested blueberries can take place. This will prevent the blueberries from being exposed to direct sunlight when there are unforeseen delays at the cold rooms.

Ensure sufficient pre-cooling and adding separate refrigerated rooms inside the cold room on the farms in the Western Cape

It is the opinion of the researcher that all farms should use forced-air pre-cooling systems. All three farms in the Western Cape failed to reach protocol temperature within the required 300 minutes (as set out by protocol), in terms of their average and median times. All farms, but specifically the farms in the Western Cape, should examine and strive to have similar cold room facilities and pre-cooling processes as applied on Farm E. The cold rooms in the Western Cape should be equipped with separate refrigerated rooms for building of pallets, pre-cooling and holding of pallets after pre-cooling. This could be a possible solution to the problems experienced in the Western Cape as the farms in Gauteng are equipped with separate refrigerated rooms and were far more consistent regarding the stage where the protocol temperature of 6°C was reached.

Loading Bays and air-lock systems

Having loading bays and air-lock systems should be a non-negotiable protocol of Company X. All role players in the blueberry cold chain should be equipped with a fully functional and working loading bay and air-lock system. This substantially decreases the occurrence of temperature fluctuations during the loading and offloading of pallets. In addition, the transportation used should be standardised reefer trucks to ensure that no fluctuation in temperature occurs during transportation or the loading and offloading of pallets, as most loading bays and air-lock systems are installed according to the dimensions of a standard reefer truck.

Installation of temperature and humidity sensitive devices in the packhouse

Even though the packhouse situated in the Western Cape has temperature sensitive devices installed in the packing room, the packing room was still the main area of concern due to the temperature spikes and temperature breaks recorded. Specific focus needs to be placed on the following of protocols and identifying more temperature sensitive areas. In addition, the installation of humidity sensors could aid in identifying possible areas where improvement is required. Furthermore, focus needs to be placed on the cold rooms, as chilling injury spikes and breaks were recorded. The cold room should be used to maintain temperatures and not decrease temperatures. In Gauteng, the holding and packing rooms were two areas of concern for this stage. Protocol dictates that the holding-, packing- and cold room maintain a temperature of 6^{o}C. Various protocols were not followed and need to be addressed. An interviewee mentioned that a new packhouse is under discussion for Gauteng. A recommendation could be to install temperature and humidity sensitive sensors in the packhouse. In the opinion of the researcher, a bigger packing room is a necessity as the confined space contributed to the high temperatures recorded in this room. Furthermore, the addition of a loading bay would be recommended as the packhouse was only equipped with an airlock system. An airlock system without a loading bay is not as effective since heat is still transferred to the holding room during loading and offloading. Lastly, the researcher recommends that both packhouses have separate locations for the loading and offloading of pallets.

Decreasing the extent of temperature fluctuations during the Forced Cooling stage

Attention should be directed to the defrosting cycles during the Forced Cooling stage. In both the Western Cape and Gauteng, the defrosting cycles were identified as an area of concern by the researcher, since the majority of temperature fluctuations recorded during this stage were a result of these defrosting cycles. The researcher recommends that Company X consider recruiting an expert to help minimize the extent of the temperature fluctuations during defrosting cycles. Furthermore, emphasis needs to be placed on the Forced Cooling stage for Gauteng specifically. All the farms in the Western Cape reached the protocol temperature within the required 600 minutes (according to protocol), in terms of their average and median times. In contrast, insufficient forced cooling was applied within the protocol time provided for all the trials in Gauteng. It is the opinion of the researcher that a possible solution for Gauteng could be for the packhouse and forced cooling facilities to be situated at the same location. In addition, it would be ideal if the packhouse and forced cooling facilities are owned by a single company, as it will help to navigate forced cooling schedules more easily and ensure sufficient cooling is applied by having more control. Furthermore, this will mean that forced cooling will be specialized for specific fruit types, contrary to Gauteng, which applies forced cooling to various types of products. For example, during this study, flowers were kept in the same location as the blueberries and protocols were not followed as discussed in section 4.9.

6.4. Future Work

6.4.1. Introduction

The blueberry industry is newly established in South Africa and is ever growing and improving. In addition, due to the competitive nature of the blueberry industry little to no information is currently available regarding the blueberry cold chain. While conducting this study, various knowledge gaps within the blueberry cold chain were identified by the researcher, as discussed below, where a more in-depth study is required.

6.4.2. Impact of humidity during pre-cooling

A study can be dedicated to investigating the impact of humidity on blueberries. Specifically focussing on the importance of humidity during pre-cooling and the role it plays in preventing blueberries from losing moisture further along the cold chain. Ladanyia (2008:329) states that during the pre-cooling of citrus fruit, fruit weight loss can be minimized even if high-air velocity is used during pre-cooling. This is achieved by maintaining a high level of humidity. Therefore, conducting an in-depth study on blueberries could be valuable to the industry if the same principles apply, as with the study published by Ladanyia (2008:329).

6.4.3. Investigating the entire blueberry cold chain

The present study focused on the initial stages of the blueberry cold chain, as Company X specifically stipulated that no noticeable problems occurred after the Forced Cooling stage. However, on various QC reports, average temperatures above 2˚C were recorded upon arrival at the destination. These high temperatures could be a contributing factor to the deterioration of pallets and could possibly be the reason why pallets are downgraded. Therefore, these findings show that perhaps further investigation is needed, specifically focussing on the cold chain of blueberries after forced cooling is applied. However, to gain a better understanding of the blueberry cold chain in its entirety, it is recommended that the beginning stages of the blueberry cold chain should also be included in the future study.

6.4.4. Field packing

During the present study, Farm C made use of field packing instead of the standardised packing used by all the other farms. In the Descriptive Data Analysis section (Chapter 4), it was evident that field packing could be a major factor in the blueberry industry owing to the short turnaround time it achieves. To elaborate, no packaging of blueberries is required, thus, eliminating the handling of blueberries as well as the Packhouse stage. This meant that Farm C spent the shortest average total time during the beginning stages of the blueberry supply chain. However, the quality control reports from Farm C showed that further investigation into maintaining the fruits quality is necessary. Both pallets from Farm C were classified as "Red Fail", with weight loss, shrivelling and soft blueberries being the major concerns. This highlights the need to conduct extensive research into the steps that should be taken to help maintain the quality of fruit if field packing is used.

The three future topics identified could have a significant financial impact on the blueberry industry, as these studies could potentially lead to achieving better fruit quality in the long term.

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Addenda

Addendum A: Survey (international blueberry experts)

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MASTERS RESEARCH: LOGISTICS MANAGEMENT
A temperature profile of the beginning stages of a blueberry supply chain.

Purpose of study

The aim of the study is to identify whether the different logistics processes implemented, specifically in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage, have an influence on the quality of the fruit. To elaborate, this study aims to help exporters of blueberries identify and address the problem of temperature breaks in the initial stages of the blueberry cold chain. Where after, this study strives to determine a link between logistics processes, temperature breaks and fruit quality.

Additional information

The survey will take approximately 15-20 minutes to complete and will contain a combination of questions covering the way tasks are executed in the initial stages of the blueberry supply chain. Please note that follow up questions might arise due to the response of the survey.

The respondent should kindly note that participation in this study is voluntary. The feedback from this survey will remain confidential and will be used solely for the MSc thesis. The respondent has the right to decline answering any questions and is free to withdraw from the interview at any given time without any explanation.

Contact details

Thank you for taking the time to participate in the survey. Should you have any questions or require additional input, please feel free to contact the researcher (Mr Petré Steynberg) or the supervisor (Prof. Leila Goedhals-Gerber) who will be assisting with the research.

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Figure A1 illustrates a South African supply chain of blueberries from harvest until they reach the cold store, starting from picking the blueberries and placing the iButton® temperature tracking device with the blueberries in the bucket and ending when the packaged blueberries reach the cold storage facility.

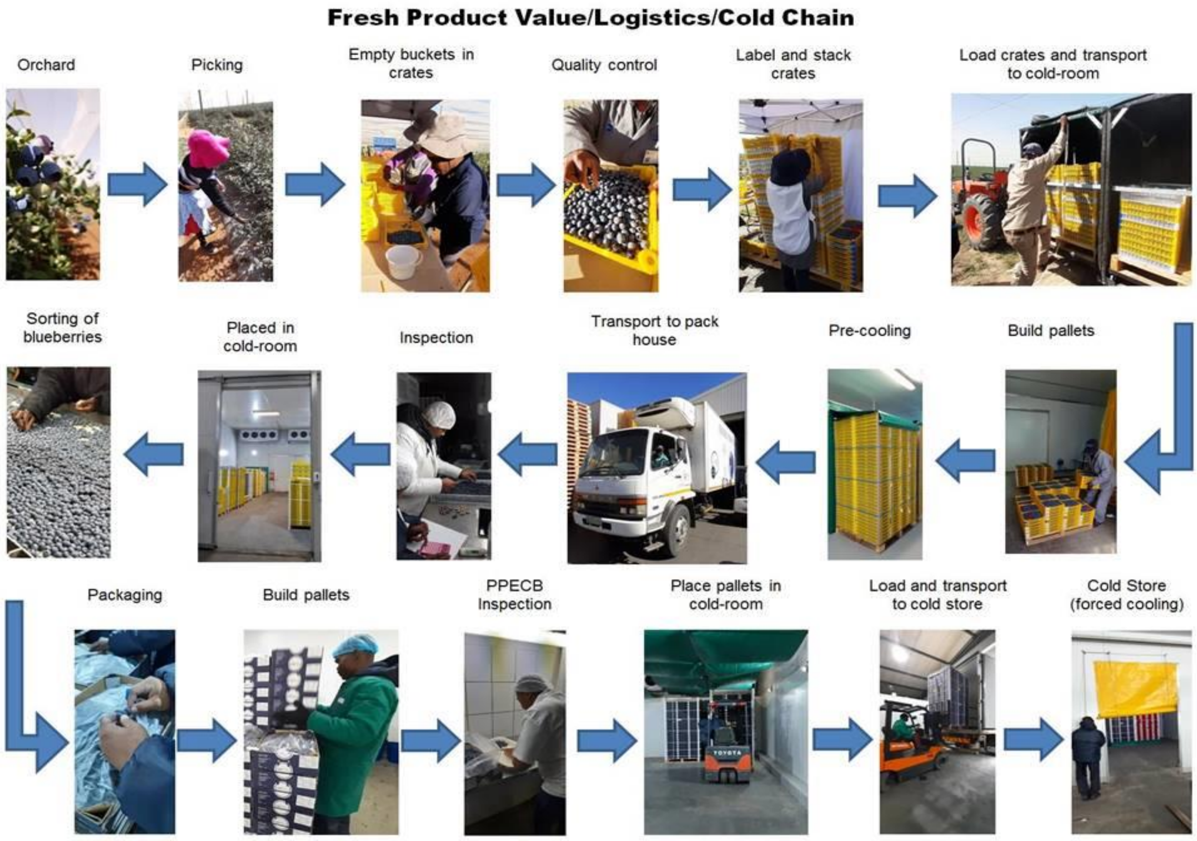

Figure A1: Blueberry Export Cold Supply Chain
Source: Created by the author for the purpose of this study

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1. After examining Figure A1, what logistical processes does your country not include/have extra in your blueberry supply chain?

____
____
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____
____

2. Why in your opinion does your country exclude or add these processes?

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____
____
____
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3. What areas in the beginning stages of the blueberry cold chain in your country do you think are problem areas and why do you think these problems might occur?

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4. On average, how long does it take to complete each process in the beginning stages of the blueberry supply chain with regards to the movement of blueberries (i.e., how long does it take for the fruit to be moved from the field to the cold room, how long does it take for the pallets to be loaded onto a truck and how long does it take for the pallets to be off-loaded at the cold store)? Is this on par with industry standards?

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5. What strategies/plans are currently being undertaken to improve efficiency in the beginning stages of the blueberry cold chain in your country?

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A temperature profile of the beginning stages of a blueberry supply chain.

Table A1 illustrates the four main protocols that need to be followed by all farmers in South Africa in order to maintain an efficient and effective cold chain. The reason for these protocols is to ensure better quality blueberries by trying to minimize the possibilities of temperature spikes taking place.

1)	The fruit should be in a cold room within 1 Hour after harvest.
2)	Fruit temperature should be brought down to 6 degrees Celsius within 4 hours after it arrives in the cold room.
3)	Fruit should arrive at the packhouse within 24 hours after harvest and should arrive at a temperature of 6 degrees Celsius.
4)	After arriving at the packhouse fruit should be packed within 24 hours and arrive at the forced cooler.
5)	Forced cooling must bring the fruit temperature down to 0 degrees Celsius.

Table A1: Protocols of Company X
Source: Supply Chain Specialist

6. After examining Table A1, what protocols does your country not include/have extra in your blueberry supply chain?

____

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7. If different protocols are being followed, would you please provide these protocols?

____

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8. Why in your opinion does your country exclude or add these protocols or have different protocols?

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Addendum B: Questionnaire (key role players in the beginning stages of a blueberry cold chain)

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A temperature profile of the beginning stages of a blueberry supply chain.

Purpose of study

The aim of the study is to identify whether the different logistics processes implemented, specifically in the beginning stages of the blueberry supply chain, from the picking process until they are loaded into cold storage, have an influence on the quality of the fruit. To elaborate, this study aims to help exporters of blueberries identify and address the problem of temperature breaks in the initial stages of the blueberry cold chain. Where after, this study strives to determine a link between logistics processes, temperature breaks and fruit quality.

Additional information

The interview will take approximately 15-20 minutes to complete and will contain a combination of questions covering the way tasks are executed in the initial stages of the blueberry supply chain. Please note that follow up questions might arise due to the response of the interviewees.

The respondent should kindly note that participation in this study is voluntary. The feedback from this interview will remain confidential and will be used solely for the MSc thesis. The respondent has the right to decline answering any questions and is free to withdraw from the interview at any given time without any explanation.

Contact details

Thank you for taking the time to participate in the interview. Should you have any questions or additional input, please feel free to contact the researcher (Mr Petré Steynberg) or the supervisor (Prof. Leila Goedhals-Gerber) who will be assisting with the research.

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9. What areas in the beginning stages of the blueberry cold chain do you think are problem areas and require improvement?

____

____

10. Which areas in the beginning stages of the blueberry cold chain are susceptible to temperature breaks occurring?

____

____

11. What measures have been put in place to reduce the occurrence of temperature fluctuations on (in) the farm/packhouse/cold store?

____

____

12. What strategies/plans are currently being undertaken to improve efficiency in the beginning stages of the blueberry cold chain?

____

____

13. What actions are taken to reduce congestion at the orchard/farm/packhouse/cold store?

____

____

14. What steps are taken should there be a backlog in the schedule (i.e., not sufficient blueberries in order to finish a pallet, power outage, etc.)?

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A temperature profile of the beginning stages of a blueberry supply chain.

15. What logistical processes (i.e., harvesting, transportation, packaging) need improvement to ensure a higher quality blueberry on arrival in the destination country?

____

____

16. On average, how long does it take to complete each process in the beginning stages of the blueberry supply chain with regards to the movement of blueberries (i.e., how long does it take for the fruit to be moved from the field to the cold room, how long does it take for the pallets to be loaded onto a truck and how long does it take for the pallets to be off-loaded at the cold store)? Is this on par with industry standards?

____

____

17. If personnel were provided with additional training, do you think it would improve the cold chain of blueberries (i.e., farm workers, truck drivers, sorters and packers, etc.)? If yes, what would the training include and what areas of the beginning stages of the blueberry supply chain would this training focus on specifically?

____

____

____

18. To what extent are blueberries harvested at the optimal time of the day?

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____

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19. What impact does the geographical location have on the growth and quality of the blueberry?

- Physical location
- Average rain fall
- Ground type
- Average temperature